SECOND EDITION

An Atlas of Glass-Ionomer Cements

A Clinician's Guide

Graham J Mount

MARTIN DUNITZ

Clinical Techniques in Dentistry

An Atlas of Glass-Ionomer Cements:

A Clinician's Guide

Clinical Techniques in Dentistry

An Atlas of Glass-Ionomer Cements

A Clinician's Guide

Second Edition

Graham J Mount, AM

BDS, DDSc, FRACDS, FICD, FADI

MARTIN DUNITZ

First published in the United Kingdom in 1990 by Martin Dunitz Ltd, The Livery House, 7–9 Pratt Street, London NW1 OAE

Second edition 1994

ISBN 1-85317-183-2

A CIP catalogue record of this title is available from the British Library.

Composition by Scribe Design, Gillingham, Kent
Colour origination by Imago Publishing Ltd
Manufactured by Imago Publishing Ltd
Printed and bound in Hong Kong

Contents

Foreword

The second edition of *An Atlas of Glass-Ionomer Cements* by Dr Graham Mount is an indication of how much progress has been made in the further development of these bioactive materials. It is only in the last decade that the dental profession has recognized their unique properties which include the ability to ion-exchange at the tooth interface, leach fluoride and maintain marginal seal over long periods. In addition, their application in medicine has expanded where special glass-ionomer cements have been developed as bone cements, particularly in the field of otolaryngology.

One of the major developments that Graham Mount has been able to include in this new edition is the light-cured or, as he prefers to call them, 'dual cure' glass-ionomer cements. These materials have attracted great interest since they have overcome some of the clinical handling problems associated with the auto cure materials, the main one being the loss of cement-forming ions when the surface is exposed to saliva. However, the development of the dual cure cements has still some way to go due to their tendency to swell in water. As yet the clinical significance of this has not been established and it is likely that we shall see further progress by the manufacturers in eliminating this problem which could involve the replacement of HEMA in the formulation by other water-soluble monomers that do not form hydrogels. The dual cure cements also allow the clinician to finish the restoration earlier without causing the catastrophic failure that can occur with the auto cure cements. It is likely that, by introducing cross-linking chains of tougher polymers into the cement, some of the undesirable properties such as low tensile strength and brittleness can be overcome.

The protection of the set surface of the auto cure cements with light-activated resins has now become standard practice, and Dr Mount pioneered this technique, much to the benefit of the dental profession. Restorations treated in this way are stronger and achieve maximum translucency, which is illustrated in this edition with confocal optical microscopy showing the excellent attachment of the resin to the cement surface.

This edition is profusely illustrated with clinical slides showing the long-term results achievable with glass-ionomer cements when the correct procedures are used. The importance of using the optimum powder-to-liquid ratios and of protecting the surface of the cement from early contamination with moisture run like a thread through the book. It is clear that Graham Mount quickly recognized these vital clinical requirements at an early stage of his research into these materials and his inquisitive mind shines through in this new edition. This is a book written by an enthusiast for enthusiasts and accurately reflects the current state of the art.

John W McLean, OBE
FDS RCS (Eng), MDS, DSc (Lond), D Odont (Lund)
Clinical Consultant,
Laboratory of The Government Chemist
London

Preface

By modern standards five years is a long time in the development of a dental restorative material. It is just five years since I completed the manuscript for the first edition of this book and already it needs to be updated to keep in touch with developments. The main change has been the introduction of the dual cure glass-ionomer cements, with the consequent modifications to clinical techniques. Not that the dual cure cements are necessarily the complete answer to the problems of clinical handling; in fact, I think it essential to emphasize that the auto cure cements are still very valuable and there are many situations where they remain the material of choice.

As described in the text *Glass-Ionomer Cements* by Wilson and McLean, the chemistry of the setting reaction of these materials is essentially an acid/base reaction between a glass powder and a poly(alkenoic acid). The major advantages arising from this combination of materials and this chemistry is the ion exchange between the cement and the tooth structure and the continuing release of fluoride ions over the life of the restoration. These properties are unique and are of great clinical value to our patients.

For reasons that are difficult to define, the profession has been rather slow to recognize these advantages and has baulked at full acceptance of the system over some perceived problems in clinical handling. The auto cure cements are not difficult to handle, but, like all dental restorative materials, require understanding and patience. Clinical results over eighteen years have given much satisfaction to many dentists and they will continue to be useful within the limits of their properties.

The inclusion of the facility of command set through light curing has been greeted with great enthusiasm and, without doubt, has introduced some advantages and improvements. The DMG Chemisch-Pharmazeutische Fabrik GmbH, Hamburg, Germany, was the first to patent a system that allowed light activation of the cement through a dual action molecule. However, they did not follow through and it was left to the 3M Company, Minnesota, USA, to pursue the principle and evolve a clinically useful material. The first product was a lining cement with limited application and GC International, Tokyo, Japan, moved quickly to evolve their own lining cement, followed shortly thereafter by a full restorative cement. 3M then marketed a restorative cement and ESPE GmbH, Seefeld/Oberbay, Germany, followed suit. Clinical placement has been facilitated and both physical properties and translucency have been enhanced. The ion exchange with underlying tooth structure is still available and the fluoride release continues.

However, not every aspect is positive. The acid/base reaction is slowed down and water uptake is increased. Abrasion resistance remains unknown because the only place to test this is in the oral cavity and the cements have not been available long enough to reliably measure this factor.

The other factor that needs to be taken into account is the 'bandwagon effect' which is a real problem in this world of marketing. The terms 'light curing' and 'glass-ionomer' are hot items at the moment and are used widely to promote materials that do not necessarily fall into the category of true light-activated glass-ionomer cements. It remains the responsibility of each operator to correctly identify the material selected because the ultimate beneficiary must be our patients.

There is still much room for improvement and research is continuing. An increase in fracture strength is theoretically possible but the problem is to achieve this within the narrow confines of clinical handling. Modified glass-ionomer cements are already being used as a bone substitute in surgery where an appliance can be pre-formed and does not have to set within three minutes in the hostile environment of the oral cavity. Future versions may or may not be light-activated and clinical handling will not necessarily be so simple. However, physical properties will certainly be improved and aesthetics maintained. Whatever else, the two essential properties of the glass-ionomer system – ion exchange with the tooth and fluoride release – must remain immutable.

Acknowledgements

A production such as this is never a one-man show and many people must be acknowledged. It seems logical to go back to the beginning and recognize Dennis Smith who first evolved the idea of using poly(alkenoic acids) in dental cements; Alan Wilson then extended the concept into the glass-ionomer cements. I have the privilege of calling both good friends and have benefited immensely from their counsel. John McLean, who guided the clinical development of the cements, is, of course, my principal support and adviser and I sought his approval before finally submitting this manuscript to the publisher. Like so many of us, I miss the support of the late Ralph Phillips who, though a scientist and not a clinician, had an extraordinarily deep appreciation of the problems faced by clinicians and was always most understanding and approachable.

The evolution of the glass-ionomer system to the stage that prompted the publication of the second edition can be attributed mainly to manufacturing companies who have directed their research and development facilities into this work. Only a few of them have shown sufficient faith in the system to devote their time and money to it and both the profession and our patients are grateful. The individual chemists involved remain shrouded in anonymity within their respective companies because, again, such work is rarely the product of a single person. At this point there are only three companies with a product that can be regarded as a genuine dual cure glass-ionomer cement and their contribution to the profession is acknowledged. Several other manufacturers have tried to enter the market but they have not yet achieved the essential balance between the acid/base reaction and the protective resin 'umbrella' which is essential to maintain the ion exchange and the fluoride release indicative of a glass-ionomer. No doubt many will succeed in the future. I am particularly grateful to the many people associated with these manufacturers who have been prepared to spend time and effort with me in my attempts to keep up with developments. I happily claim personal friendship with many of them and I admire their dedication to both their company and this profession. I have always regarded the dental supply industry as a very important link in the chain of professional services which leads to the ultimate benefit of our patients. Manufacturers' representatives constitute another link in that chain and a lot hinges on their honesty and integrity. Some of my close friends belong in that chain and I owe them a substantial debt.

I have fortunately been able to continue my research at the Dental School in Adelaide under the guidance of Owen Makinson and with the support of Raoul Pietrobon, our Laboratory Manager, and I am grateful to both for their support. I am also grateful to all the dental students who have undertaken Vacation Research Scholarships in our Laboratory, and particularly to the Australian Dental Research Fund who offer generous financial support to them. They have been of considerable support in carrying out many of the rather dull repetitive exercises that constitute *in vitro* research. In addition, I appreciate the support of South Australian Dental Services for allowing continuing access to all the facilities under their control.

The photographs taken by Dr. R. Smales are again acknowledged and I would particularly like to thank Dr. T. Watson, Guy's Hospital, London, for allowing me to include four of his illustrations taken through a confocal optical microscope. This is a minimally intrusive method of examining a material that is so susceptible to damage through dehydration and is therefore rather difficult to photograph.

Finally, I gratefully acknowledge the continuing support of my wife, without whom very little indeed would ever be completed. We still share a study/sewing-room and her productivity is high.

Sources

Some illustrations have already been published and are reproduced here with kind permission:

Clarke JW, ed, *Clinical Dentistry* (Harper & Row: New York 1984) vol 4, chap 20A: Figures 1.22, 1.23;

Mount GJ, Glass-ionomer cements: obtaining optimum aesthetic results, *Dental Outlook* (1988) **14**: 3–6: Figures 1.22, 1.23, 1.26, 1.27, 1.30;

Mount GJ, Glass-ionomer cements in gerodontics. A status report for the American Journal of Dentistry, *Am J Dent* (1988) **1**: 123–8: Figures 6.67–6.72;

Mount GJ, Clinical requirements for a successful 'sandwich'—dentine to glass-ionomer cement to composite resin, *Aust Dent J* (1989) **34**: 259–65: Figures 1.29, 5.3–5.6;

Mount GJ, Adhesion of glass-ionomer cement in the clinical environment, *Oper Dent* (1991) **16**: 141–8: Figure 1.53;

Mount GJ, Clinical placement of modern glass-ionomer cements, *Quint Int* (1993) **24**: 99–107;

Watson TF, Billington RW, Williams JA, The interfacial region of the tooth/glass ionomer restoration: a confocal optical microscope study, *Am J Dent* (1991) **4**: 303–10: Figures 1.39, 1.40;

Watson TF, Banerjee A, The effectiveness of glass-ionomer surface protection treatments: a scanning optical microscope study, *Eur J Prosthodont Rest Dent* (1993) **2**: 85–90: Figure 1.19.

1 Description of glass-ionomer cements

The glass-ionomer cements are water-based cements, probably more accurately known as glass-polyalkenoate cements. They consist of an aluminosilicate glass with a high fluoride content, interacted with a poly(alkenoic acid). The result is a cement consisting of glass particles surrounded and supported by a matrix arising from the dissolution of the surface of the glass particles in the acid. Calcium polyacrylate chains form quite rapidly following mixing of the two components, and develop the initial matrix that holds the particles together. Once the calcium ions are involved, the aluminium ions will begin to form aluminium polyacrylate chains, and, since these are less soluble and notably stronger, the final matrix formation takes place. At the same time fluoride is released from the glass particles in the form of micro-droplets which lie free within the matrix, but play no part in its physical make-up. Thus the fluoride is able to leach out of the restoration as well as return into it, and a restoration can be regarded as a fluoride reservoir.

The fluoride is used initially as a flux in the manufacture of the glass particles, and has been shown to be an essential part of the setting reaction. It represents approximately 20% of the final glass in the form of minute droplets. These become available from the matrix more readily than they were from the original glass particles.

Approximately 24% of the set cement is water. This has been somewhat arbitrarily divided into 'loosely bound' water, which is easily removed by dehydration, and 'tightly bound' water, which cannot be removed and remains an important part of the setting reaction. It is essential to be aware that *in the early stages following mixing* the calcium polyacrylate chains remain highly soluble in water, so further water can be taken up. Conversely, the loosely bound water can be lost by evaporation if the cement is exposed to air. This problem of water loss or water uptake, that is, the *water balance*, is probably the most important and least understood problem with this group of cements (Figures 1.1 and 1.2).

However, recent modifications to the setting reaction through the inclusion of various resins has led to the development of the 'dual cure' (light-activated) cements. It seems that with these cements the resins provide some degree of protection to the setting reaction immediately following light initiation, preventing further water uptake or water loss. There will be some modification of the acid/base reaction because of the cross-linking with the resins, but the clinical placement routines have been simplified and the physical properties are improved to a reasonable extent.

The terms *auto cure* and *dual cure* have been arbitrarily introduced to differentiate between the two main setting reactions without defining the actual chemistry that may be taking place in any one cement.

Auto cure cements set by chemical reactions alone, currently defined as an acid/base reaction.

Dual cure cements are set initially via a light-activated reaction, but the acid/base reaction is not substantially altered and will continue over time. With some materials there may be additional reactions, but essentially there are two basic setting mechanisms involved.

Setting reaction of the auto cure cements

With the original auto cure (chemically set) cements the chemical reaction initiated by the application of poly(alkenoic acid) to the surface of the glass particles is, in fact, very prolonged (Figure 1.3). The initial set will reach a stage

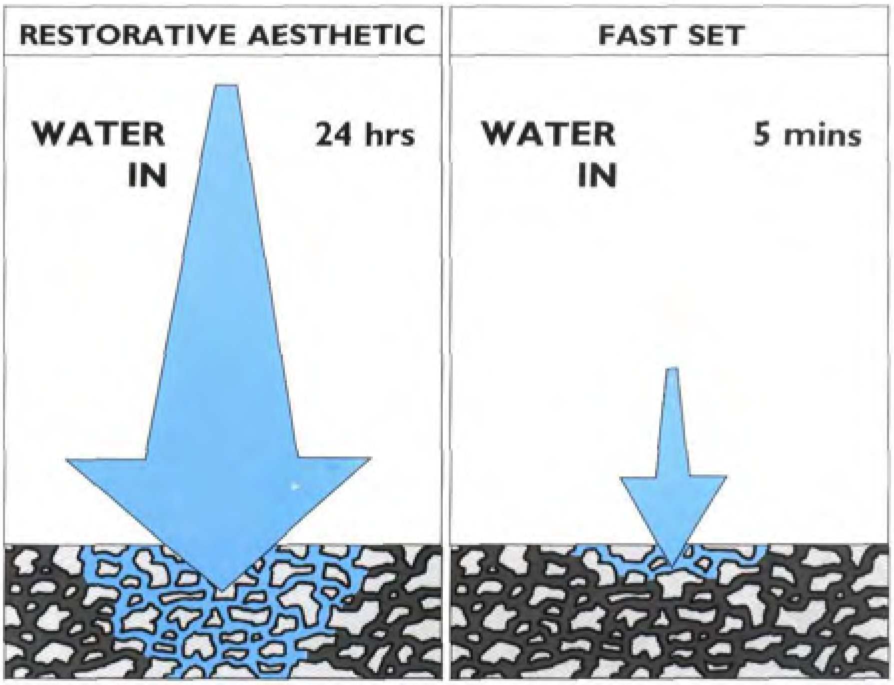


Figure 1.1

Diagrammatic representation of the water balance in the glass-ionomer cements. Restorative aesthetic cements remain susceptible to water uptake for at least 1 day after placement. Fast-setting cements are resistant to water uptake within 5 minutes of the beginning of mix.

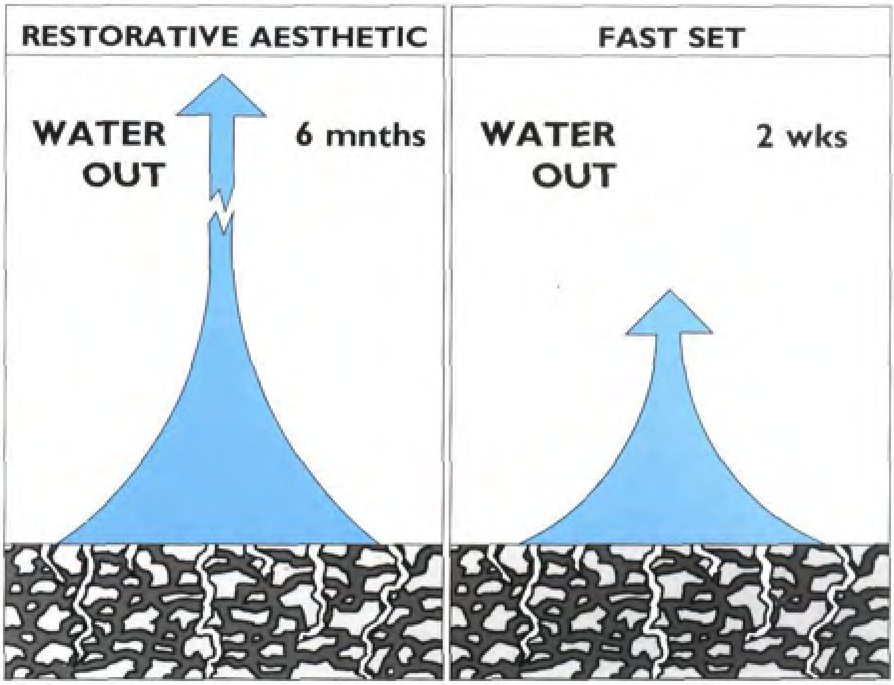


Figure 1.2

The problem of water loss continues for a longer period for both the fast- and the slow-set varieties, and precautions must be taken to prevent dehydration.

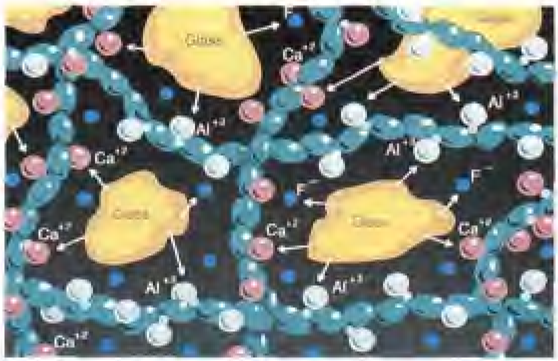


Figure 1.3

A theoretical diagram of the acid/base reaction between the glass powder and the poly(alkenoic acid). Note that only the surface of each particle is attacked by the acid, releasing Ca and Al ions as well as fluoride droplets, which remain free and are not part of the matrix. The calcium polyacrylate chains form first, and then the aluminium chains follow immediately.

within 4 minutes at which it is possible to remove a matrix and carry out trimming of the newly placed restoration. However, complete maturity and resistance to water loss will not be available for at least 2 weeks for the fast-setting varieties and possibly 6 months for the slow-setting aesthetic cements.

If it is necessary to allow the cement to come into contact with water within minutes of placement then a fast-set cement is required. However, achievement of rapid resistance to water uptake can only be gained with the sacrifice of aesthetics. In the manufacturing process, excess calcium ions are stripped from the surface of the glass particles so that the aluminium ion exchange will commence earlier in the life of the cement. Ultimate physical properties may not be reduced, but translucency is lost.

However, it must be recognized that this early resistance to water uptake does not lock in the loosely bound water, and all of the fast-setting cements remain subject to dehydration. This means that, when using them as a lining, for example, they should not be left exposed to air any longer than is necessary, since the cement is likely to crack.

If it is important to achieve an aesthetic end result in the restoration then acceleration of the setting procedure is not possible and the clinician must accept the resultant problems of maintaining a stable environment for the newly placed restoration. Considerable water uptake and water loss can occur in these cements for at least 1 hour, and may continue for a further 24 hours on a reducing scale. Thereafter, water uptake is of less significance, although water loss will remain a problem. If a relatively young restoration is to be exposed again to dehydration in the first 6 months after placement, it should be sealed with a waterproof coating to minimize water exchange.

Considerable effort is being expended at present on overcoming these problems of water balance. It has been suggested that the profession is intolerant of the time taken up by the setting reaction and that faster-setting cements, particularly lining cements, are necessary. Certainly conservation of time is important during clinical placement, but it is even more imperative that the inherent advantages of chemical union to enamel and dentine, as well as that of continuing fluoride release, are not reduced or eliminated in the process.

Setting reaction of the dual cure cements

The full chemistry of the dual cure cements is not yet fully understood. Some years ago a dental manufacturing company in Germany (DMG Chemisch-Pharmazeutsche Fabrik GmbH) developed a double action molecule capable of reacting with a poly(alkenoic acid) as well as with the vinyl groups of certain resins. Having patented the process, they did not develop the concept any further. Recently several other dental manufacturers have rediscovered this molecule and utilized it in the production of the dual cure glass-ionomer cements.

There appear to be several modifications of the basic principle available, depending on which resins are included and also the relative proportion of glass-ionomer cement compared to resin. It is apparent that hydroxyethyl methacrylate (HEMA) is a necessary ingredient to facilitate the chemical reaction, although it is highly hydrophilic and may lead to water uptake over time. Each manufacturer then adds further components with the object of protecting the original acid/base reaction between the ionomer glass and the poly(alkenoic acid) without interfering with it.

From the clinical point of view, the interaction between tooth structure and the cement that produces adhesion through the ion-exchange layer is very important. Also the long-term fluoride release should not be interfered with. However, if the addition of further resins will protect these two factors and allow the glass-ionomer acid/base reaction to continue while at the same time enhancing the physical properties then clinical placement will be simplified and the restoration may be more reliable.

A simplified diagrammatic representation of the setting reaction is shown in Figures 1.4 and 1.5. The original acid/base reaction demonstrated in Figure 1.3 appears to continue without interruption, and the resin component, following light activation, seems to provide an umbrella effect, protecting the cement from early loss of loosely bound water and further uptake of water through the dissolution of the calcium polyacrylate chains (Figure 1.4). There is probably some degree of interaction between the two components, but both reactions seem to proceed without interference. Over time, the remaining resin that was not affected by light activation appears to undergo a further chemical setting reaction (a 'dark cure reaction') similar to that which occured with the original chemically cured composite resins—hence the terms 'tri-cure' or 'triple cure' used by some manufacturers (Figure 1.5).

Recent laboratory investigations suggest that this is a reasonable hypothesis. Tests on the physical properties show a continuing improvement over the first 5 days following mixing (Figures 1.6 and 1.7), suggesting that the chemical setting reaction has not been inhibited. Specimens maintained in the dark free of any light activation will begin to set chemically within 5–7 minutes, and will achieve physical properties similar to those achieved by light activation.

Translucency testing shows that the dual cure cements react in a similar fashion to the auto cure cements. Following light activation, translucency declines marginally over the next 24 hours, but within a week the cement is more translucent than originally. Furthermore, placement of the specimens in water immediately after light activation will not modify this effect (Figure 1.8).

The depth of cure of the cement as the result of light initiation is consistently 3–4 mm, but, owing to the ongoing chemical setting reaction, this is not significant. Any cement not cured by light will continue to set, so the restoration will achieve physical properties that will be relatively uniform throughout. This appears to provide a safety margin in the average restoration, in as much as unreacted cement below 4 mm will set and achieve acceptable physical properties. However, it is suggested that the ion exchange between tooth structure and the auto cure component in some of the dual cure cements may not be strong enough, and a degree of caution is recommended.

Incremental build-up is probably the safest way of placing any light-activated restorative material, because there is inevitably some degree of shrinkage due to the immediate setting reaction in the direction of the light. This may be controlled to a certain extent by careful placement of the light, but some degree of stress on the newly forming ionic bond is almost unavoidable. The shrinkage in these materials seems to be minimal, but it does exist and therefore caution is required.

The non-glass-ionomer cements

There is some confusion in the market because the term *glass-ionomer cement* is being rather loosely used by some manufacturers. As suggested above, the essential elements of a true glass-ionomer cement are the ion exchange with the underlying tooth structure and the continuing fluoride release. For these to be available it is necessary to have a poly(alkenoic acid) present in the formula in an ionizable form. As the balance in the formula moves further to the right (Figure 1.9), away from the acid/base reaction, and the resin component predominates, the cement is no longer a glass-ionomer, and should not be recognized in that category.

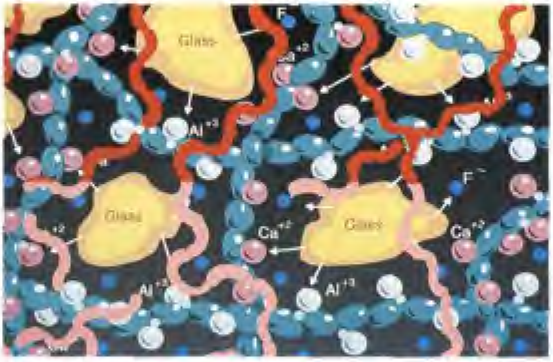


Figure 1.4

A theoretical diagram showing the influence of the resins incorporated into the glass-ionomer cement to allow for a dual cure mechanism. The resins alone are light-activated to whatever depth is allowed by the penetration of the activator light. This appears to be sufficient to protect the acid/base reaction of the glass-ionomer cement from water uptake and water loss. The red chains represent fully activated resins to the depth of penetration of the activator light.

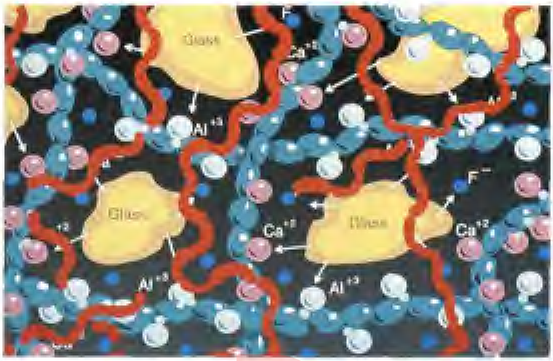


Figure 1.5

A theoretical diagram showing the progress of the chemical setting reaction of the resin component of the dual cure cement. Light activation will be limited to the light penetration, but a 'dark cure' reaction will continue until the entire cement/resin mass is set. The red chains now represent the completion of the 'dark cure' of the resins.

Figure 1.6

A bar chart showing the relative strengths of some auto cure cements as measured by a shear/punch test compared with two composite resins: Pertac Hybrid and Z100. Note that each cement is stronger at 5 days than at 2 hours—evidence of the continuing setting chemistry.

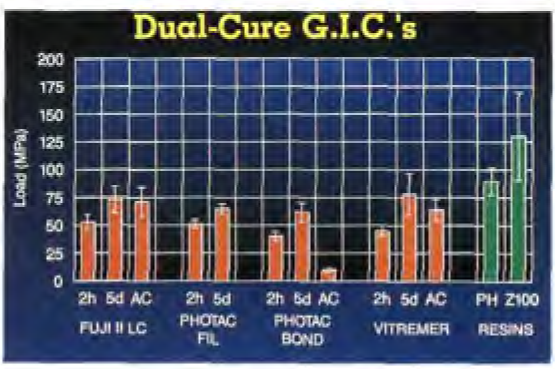


Figure 1.7

A bar chart showing the relative strengths of some dual cure cements as measured by a shear/punch test compared with two composite resins: Pertac Hybrid and Z100. Note that each cement is stronger at 5 days than at 2 hours—evidence of the continuing setting chemistry. Note also the strength of the specimens that were allowed to auto cure only for 5 days—evidence that the acid/base reaction is not altered by the presence of the resins.

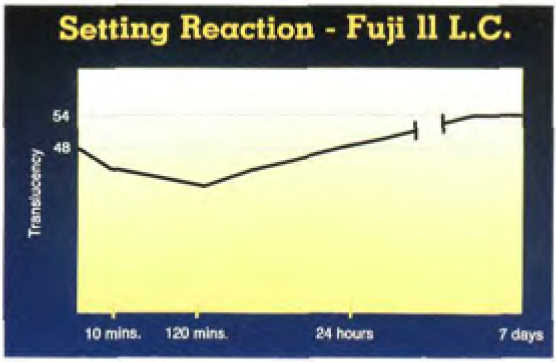


Figure 1.8

A chart showing the initial decline in translucency over the first 24 hours after mixing, followed by an increase over the following 7 days to a point where the cement is more translucent than initially.

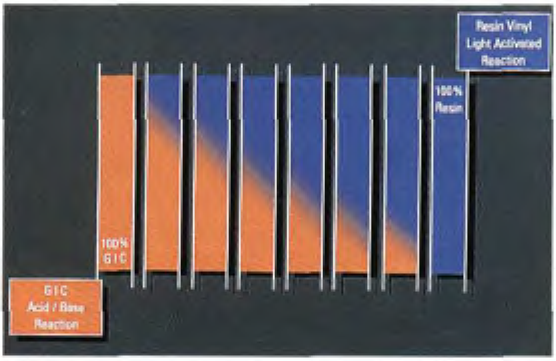


Figure 1.9

A diagram showing the theoretical composition of various dual cure cements and the potential effect of modifying the relative percentage of the contents. As the resin component increases, the acid/base reaction reduces, until the benefits of the glass-ionomer cement are lost and the material becomes a light-activated cement only.

Figure 1.10

A trial mix of a non-glass-ionomer cement has been placed under a light-proof cover and is being tested against the timing clock.

Figure 1.11

At 20 minutes the mix is tested for degree of set. This particular material shows no sign of setting at this point.

Figure 1.12

A similar trial mix of a true dual cure glass-ionomer cement is set against the clock.

Figure 1.13

At 7 minutes the cement is well set and, obviously, the acid/base reaction is taking place.

There are now several such materials available to the profession, and some of them are marketed in such a manner as to be confusing. They are quite useful cements when used as liners or restorative materials, as indicated by the manufacturers, but it should not be expected that they will provide the properties normally identified with the glass-ionomer cements.

The most obvious difference between the two types of material is that the proper glass-ionomer cement is a true dual cure in as much as it will undergo a chemical cure if it is not light-activated. This means that the simplest method available to the clinician to differentiate between the two is to make a trial mix and retain the cement under a light-proof cover for 5–7 minutes. At this point the cement should be showing clear signs of a chemical set. It should be quite firm, and over the next 15–20 minutes still protected from light, it should set quite hard. The non-glass-ionomer cements will stay very soft and rubbery or else not set at all (Figures 1.10–1.13).

Any adhesion developed with the underlying tooth structure by the non-glass-ionomer cements will be essentially a resin-type adhesion, and therefore subject to long-term hydrolysis and subsequent breakdown. Also fluoride release will decline rapidly and will not be sustained over the long term.

It is therefore suggested that these materials be used carefully, with an understanding of their limitations and without the expectations for longevity and caries resistance associated with the true glass-ionomer cements.

Classification

The following classification is adapted from Wilson and McLean (1988). It is generally accepted, and will be used throughout this book.

Type I: Luting cements

- For cementation of crowns, bridges, inlays and orthodontic appliances.
- Powder/liquid ratio approximately 1.5 : 1.
- Fast set with early resistance to water uptake.
- Ultimate film thickness 25 μm or less.
- Radiopaque.

Type II: Restorative

II.1: Restorative aesthetic—auto cure and dual cure

- For any application requiring an aesthetic restoration; the only limitation is no undue occlusal load.
- Powder/liquid ratio 2.8 : 1 to 6.8 : 1.
- Excellent shade range and translucency.
- Auto cure cements have a prolonged setting reaction and remain subject to water loss and water uptake for at least 24 hours after placement; **they require immediate protection from the oral environment.**
- Most auto cure cements are radiolucent.
- Dual cure cements are immediately resistant to water uptake or water loss; **they do not require sealing.**
- Most dual cure cements are radiopaque.

II.2: Restorative reinforced

- For use where aesthetic considerations are not important but a rapid set and good physical properties are required.
- Powder/liquid ratio 3 : 1 to 4 : 1.
- Fast set with early resistance to water uptake; can be trimmed and polished immediately after initial set; remain susceptible to dehydration for 2 weeks after placement.
- Radiopaque.

Type III: Lining or base cements

- Can be auto cure or dual cure.
- Can be used as either a *lining* or a *base*, depending on the powder/liquid ratio used.
- Powder/liquid ratio 1.5 : 1 for use as a lining material under other restorative materials.
- Powder/liquid ratio 3 : 1 or greater for use as a base or dentine substitute in combination with another restorative material.
- Physical properties improve as the powder content increases.
- Radiopaque.

Significant factors

Powder/liquid ratio

It is important to be aware that the constituents of the various glass-ionomer cements on the market are not the same. There is, in fact, a considerable difference between the powders and liquids produced by various manufacturers, and products must therefore never be interchanged. It should also be noted that, in some cases, materials marketed under different names are made by the same manufacturer.

The thermal history of the glass during manufacture has a bearing on the clinical handling and ultimate physical properties of the cement. In the earlier formulations in particular, the glass powders are of a high-fluoride variety to allow for a rapid setting reaction, and these glasses are rather opaque. Another method of speeding the setting reaction is to deplete the available calcium ions on the surface of the powder. This also will be at the expense of aesthetics, but will result in a cement with an early resistance to water uptake. The introduction of tartaric acid into the formula to speed up the setting reaction led to the use of glasses of lower fluoride content, which are notably more translucent, and these are particularly valuable in the Type II.1 restorative aesthetic cements.

Powder particle size varies between both manufacturers and cement types. Generally, the slower-setting aesthetic cements have particles ranging up to 50 μm in size, while the faster-setting luting and lining cements have a finer parti-

cle distribution. Smaller particle size speeds the chemical reaction, and also improves the chance of achieving a fine film thickness.

In the original formula the liquid was a poly-(acrylic acid), and this posed difficulties. Higher molecular weight and concentration of acid increases strength and accelerates setting time. However, the viscosity of the liquid also increases as the molecular weight goes up, and clinical handling becomes difficult. In addition, the viscosity of the acid tends to increase during storage, which makes dispensing and mixing more difficult still. Subsequently, copolymers of acrylic acid with other unsaturated carboxylic acids, such as itaconic acid and maleic acid, were developed, and these proved more reliable, easily handled and stored. As long as the polyacid is present in solution, however, the problem of increased viscosity with an increase in molecular weight or concentration remains. Hence the present trend is towards utilizing a dehydrated form of polyacid and incorporating it in the powder, using either water or dilute tartaric acid as the liquid. The resultant mixed cement has a relatively low viscosity and is therefore easier to handle, and it is particularly suitable as a luting cement.

Because, in the anhydrous form, acids of higher molecular weight can be incorporated, the physical properties of these cements are generally superior. Certainly, shelf life is improved, hand-mixing on a glass slab is easier and a fine film thickness can be achieved more readily with the luting cements.

As with all dental restorative materials, the powder/liquid ratio has a significant bearing on ultimate physical properties. To a certain extent, the greater the amount of powder the higher the ultimate properties. However, where there is insufficient liquid to wet the powder particles, a point will be reached where translucency will decline, in the presence of unreacted particles.

Lower powder ratios are required with the luting cements so that optimum film thickness can be achieved. Also, when using the cement in small quantities as a lining under other restorative materials, such as amalgam or gold, it is more readily handled with a lower powder content, and physical properties will not be of great significance. However, if it is to be a base under composite resin then physical properties will be significant and a high powder/liquid ratio is indicated.

Hand-mixing of these cements is possible, but considerable variation in the powder content will result unless extreme care is taken in measuring out when dispensing. Hand-mixing at the higher powder/liquid ratios for the restorative cements is very difficult, and capsulation is strongly recommended as being the ideal method of dispensing. The powder/liquid ratio can be standardized, as well as the mixing time and therefore the setting time. Ultimate physical properties will then not be in doubt.

When mixing mechanically, care must be taken to see that the correct time is used according to the machine available. Manufacturers generally suggest 10 seconds with a machine capable of 4000 cycles/min. These are generally known as 'ultra-high-speed' amalgamators, but some machines will produce up to nearly 5000 cycles/min and may therefore over-mix and reduce working time.

The estimation of effective working time can be made by determining the 'loss of gloss' of the newly mixed material (see Box A, page 10). Careful observation of a sample mix will show when the gloss goes off, and placement of the cement after that point will risk failure. Working time should be at least 2 minutes from the completion of mix, and this will normally be achieved with a mixing time of 7–10 seconds. A shorter mixing time may leave unreacted liquid visible in the cement, while a longer period will result in an unacceptably short working time.

There is a degree of porosity incorporated in all of these cements, which is unavoidable. There appears to be a greater variation in the size of porosities when the cement is hand-mixed. Machine-mixed capsulated cement demonstrates similar porosity, but the voids are uniformly smaller. Surface porosity will result, on occasion, in uptake of surface stain.

Time to mature

The setting reaction of the glass-ionomer cements can be described as an ionic cross-linking between polyacid chains, giving a rigidly bound polyacid/salt matrix. The initial cross-linking involves the more readily available calcium ions, producing an early set to allow removal of the matrix. However, these divalent linkages are

BOX A MIXING OF CAPSULES

Trituration of capsules of glass-ionomer cements is not necessarily a straightforward procedure. Manufacturers give a recommended time for capsules in a so-called high-energy amalgamator, but it must be realized that not all amalgamators are the same and, probably more important still, all amalgamators can vary in the amount of energy dispensed on any given day.

A high-speed amalgamator works at approximately 3000 cycles/min.

Ultra-high-speed amalgamators work at approximately 4500 cycles/min.

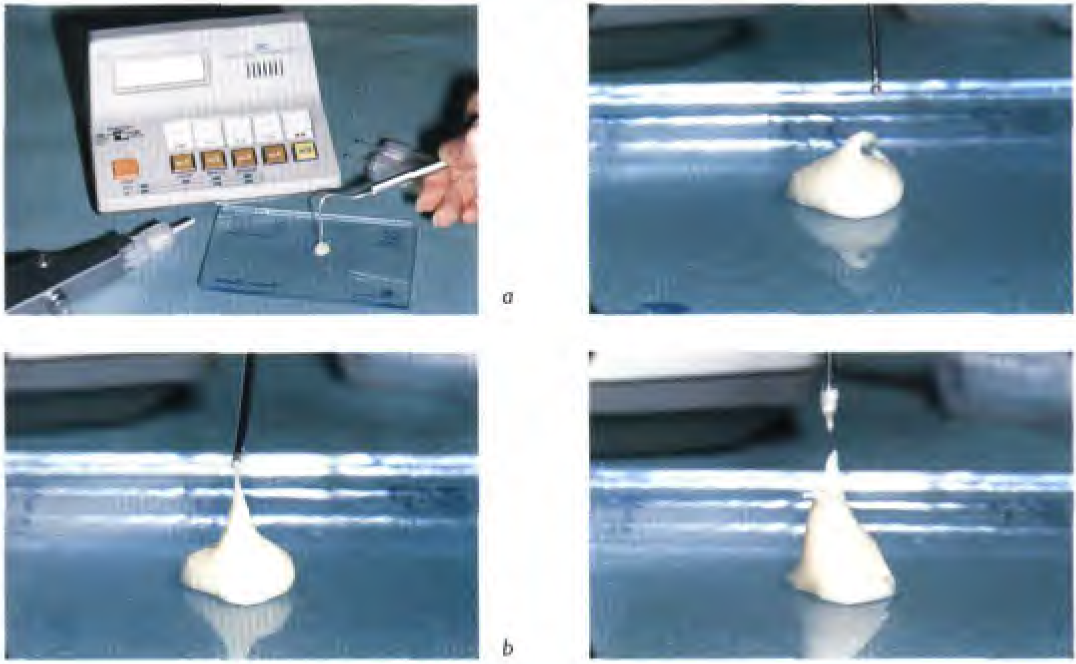
However, the number of cycles may vary by as much as 10% on either side of this figure under normal circumstances, and factors such as ambient temperature, power surges, manufacturer variation, and age of the machine can produce much greater differences. The operator should therefore be prepared to check the state of the mix periodically to ensure a predictable and standard result.

Check the efficiency of your machine by assessing the 'loss of gloss' of a freshly mixed capsule.

Determining the 'loss of gloss'

- Mix a capsule for 10 seconds and express the contents onto a glass slab in a single pile. Start the timer (*a*).
- The material will have a wet glossy surface and will slump down on the slab without spreading out.
- Using a dental probe or small instrument, touch the top of the pile and lift the cement up. It should string up 2.0 cm or so from the top, then break away and slump back to its original shape (*b,c*).
- At some point, the glossy surface will begin to dull. The material will no longer string out as far as before, nor will it slump to its original form (*d*).
- Note the time. Subtract 15 seconds, and the remainder is the effective working time available at that mixing time with that machine.
- Vary the mixing time as required to set the correct working time for your situation.
- Extending the mixing time may produce a mix that will flow better, but the rise in temperature produced by the increase in energy expended may reduce the working time quite dramatically.
- Reducing the mixing time may produce a mix that will flow more readily because not all the liquid has been utilized. Working and setting time will then be considerably extended but physical properties will be downgraded.

Bass EV, Wing G, The mixing of encapsulated glass-ionomer cement restorative materials, *Aust Dent J* (1988) **33**:243.



a b c d

Determining the 'loss of gloss' (see Box A).

not stable and are readily soluble in water. The setting reaction continues within the hard cement mass with further cross-linking by the less-soluble trivalent aluminium ions. This second phase produces an increase in physical properties, along with a reduction in solubility, resulting in a hard, stable, brittle material with a highly linked polyacid/salt matrix. It is possible to increase the speed of this reaction, with a dramatic reduction in the time taken for the development of the calcium polyacrylate chains and therefore an early resistance to water uptake and lowered solubility. This can be achieved at the manufacturing stage by the removal of excess calcium ions from the surface of the glass particles, and this is the technique generally utilized for the fast-setting Type I and Type III cements.

The alternative technique for protecting the setting reaction without interfering with the acid/base reaction is the inclusion of further resin, in particular hydroxyethyl methacrylate (HEMA) and other light-activated resins. This will produce dual cure cements that appear to be resistant to water uptake immediately after light curing, and will require no further protection. The presence of the additional resins will modify the acid/base reaction to some degree and slow it down but, in the long term, the entire restoration appears to achieve a complete set. It must be noted that the cement will only be set to the depth of the penetration of the curing light, so any necessary contouring should be undertaken with care, and final polishing delayed as long as possible. Application of a sealant is not required for water stability, but a final application of a glaze is desirable to fill surface porosities and ensure the surface is smooth.

In view of this immediate set, the use of the dual cure cements is not confined to Type II.1 restorative aesthetic restorations. They can be

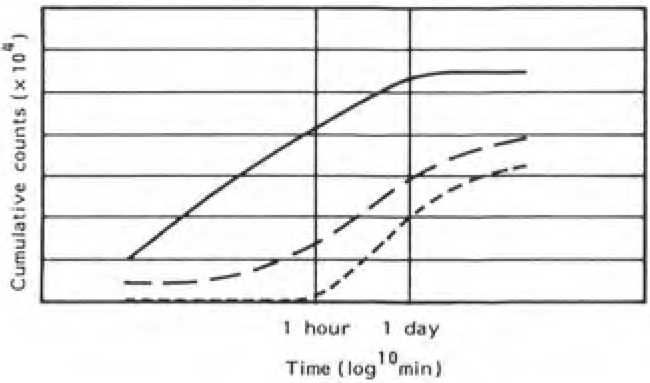


Figure 1.14

Relative efficiency of proprietary varnishes and a single-component, low-viscosity, light-activated bonding resin as sealants, to maintain water balance within the cement. The resin bond gives more water retention at 24 hours and therefore better physical properties and greater translucency.

——	Control
— — —	Proprietary varnish
- - -	Low-viscosity, light-cured resin bonding agent

Figure 1.15

Class V glass-ionomer cement restorations in the upper-right canine and both bicuspids, 5 years after placement. They were sealed with a very low-viscosity, light-activated bonding resin and display excellent colour and translucency.

used in a great variety of situations, and, particularly because of enhanced physical properties, they make an excellent base or dentine substitute under composite resin, and can be used as a Type II.2 restorative reinforced cement for a core build-up.

However, with the auto cure cements the rapid setting times can only be achieved at the expense of colour and translucency, so that, if a Type II.1 restorative aesthetic cement is to be utilized, to obtain optimum results it is necessary to protect the setting cement against water uptake for some hours after placement. In certain materials physical properties at 15 minutes may be sufficient to allow contouring and polishing of the newly placed restorations. However, if disturbed at this point, there will be sufficient water uptake to reduce the translucency to unacceptable levels, as well as to lower the physical properties and, therefore, the attachment to dentine.

The maintenance of water balance for 24 hours allows optimum development of aesthetics and is recommended (Figures 1.14 and 1.15).

Manufacturers provide a varnish to seal the newly placed restoration from the oral environment, but this has proved to be less than ideal. The varnish has an evaporative vehicle incorporated in it and therefore porosities are likely to appear as the vehicle evaporates (Figure 1.16). If the varnish is carefully applied and the vehicle evaporated, followed by a second coat carefully blown dry, a reasonable result can be achieved.

(*contd p. 17*)

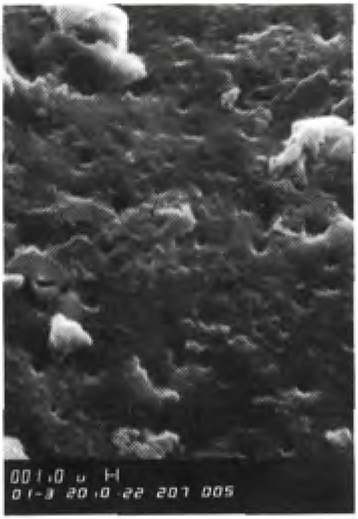


Figure 1.16

SEM of proprietary varnish recommended for sealing glass-ionomer cements. Note the relative porosity. *Original magnification × 1000.*

Figure 1.17

SEM of single-component very low-viscosity, light-activated resin bonding agent. Note the lack of porosity. *Original magnification × 1000.*

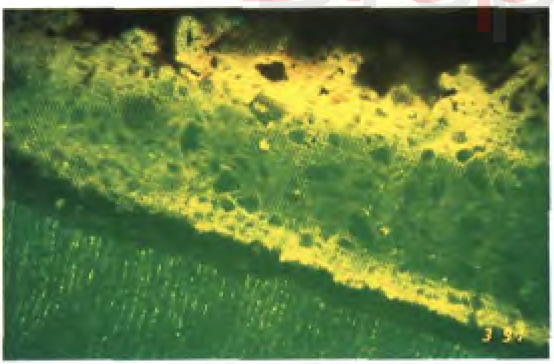


Figure 1.18

A *confocal optical microscope* study of a section through a glass-ionomer cement restoration that has not been protected during setting and was subsequently soaked in rhodamine B dye solution. Note that the cement has lifted off the dentine and there is severe degradation of the surface with penetration of the rhodamine dye to the full depth of the cement. (Courtesy of Dr TF Watson.)

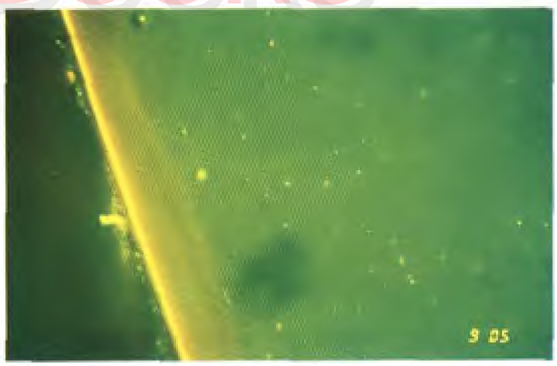


Figure 1.19

The cement on the right of the illustration has been sealed with a very low-viscosity, light-activated resin sealant containing maleic acid (yellow band on the left of the illustration—the bright yellow line is the oxygen-inhibited layer on the surface of the resin). Note the excellent adaptation of the seal and the complete integrity of the cement. (Courtesy of Dr TF Watson.)

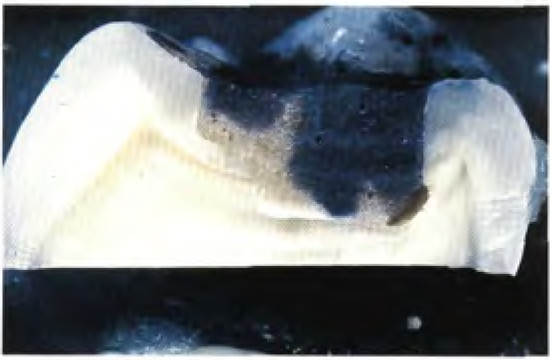


Figure 1.20

Class I glass-ionomer cement restoration, placed in the occlusal surface of an extracted molar tooth. It was covered with a proprietary varnish and immersed in dye 7 minutes after placement. There is severe penetration of the dye into the cement. (Courtesy of Dr R Smales.)

Figure 1.21

Similar restoration that has been sealed with a single-component, low-viscosity, light-activated resin bonding agent. Note the complete lack of dye penetration. (Courtesy of Dr R Smales.)

Figure 1.22

Glass-ionomer cement restorations on the labial surface of both upper-central incisors. The restoration on the left-central was placed 2 years prior to the right-central and was protected with a proprietary varnish. Note the white defect on the left-central. The restoration on the right-central was properly protected with a low-viscosity resin seal.

Figure 1.23

When the restorations are dried off, the white defect is more pronounced. However, the restoration in the right-central, which was protected at insertion with a light-activated resin bond, remains unaffected by dehydration.

Figure 1.24

Polishing back the restoration in the left-central shows that the defect penetrates through the entire depth of the cement.

Figure 1.25

Labial erosion lesions on the two upper-central incisors before treatment.

Figure 1.26

The lesions were restored with glass-ionomer cement 5 years prior to this photograph, and were protected at insertion with copal varnish only. They appear to have been both hydrated and dehydrated during placement procedures, and require replacement.

Figure 1.27

The restorations were replaced with another glass-ionomer cement and protected with a very low-viscosity, light-activated bonding resin. They had been in place for 2 years when photographed.

Figure 1.28

Three Class V restorations placed on different occasions. The restoration in the upper-right canine was placed 10 years ago and was not properly protected. It therefore remains subject to dehydration and lacks translucency. The two bicuspids were restored approximately 5 years ago and were properly protected.

Figure 1.29

Class V restorations in the upper-left central and lateral incisors, both of which were allowed to dehydrate shortly after placement. The restoration in the central incisor is cracked, and the one in the lateral has suffered bulk failure as a result.

Figure 1.30

Class V restorations in the upper-left central, lateral and canine. The upper-central restoration has been in place for over 1 year and was properly protected. The restoration in the canine was placed 6 months previously and was regarded as mature. However, as the restoration was being placed in the lateral incisor, the cement in the canine dehydrated on the surface after approximately 10 minutes' exposure to air, showing that even at 6 months it was not completely mature.

Figure 1.31

Class V restorations were placed in the upper-left canine and both bicuspids 24 hours previously, and they were protected with a generous coat of bonding resin. There are still small projections of resin remaining at the gingival margins, which may retain plaque and should be removed.

Careful drying should be carried out for approximately 30 seconds for each coat of varnish before allowing the restoration to get wet.

The most efficient seal can be obtained by using one of the single-component, very low-viscosity, light-activated, unfilled bonding resins, which are part of the composite resin system, instead of the varnish (Figures 1.17–1.19). It has been shown that lower viscosity permits better adaptation of the resin to the cement surface, and therefore a better seal. Bonding agents that need to be premixed and contain an evaporative vehicle to reduce their viscosity will not be effective, because they are likely to be porous when set, therefore allowing water exchange through the resin film. The same applies to chemically activated bonding agents, which, of course, require hand-mixing, with the consequent potential for incorporation of air bubbles and porosities (Figures 1.20–1.29).

Recent work has shown that the layer of bonding resin will remain on the surface of the restoration for some time, depending upon the vigour of the patient's brushing routine. Using a specially prepared Visio-Bond containing a fluorescent dye, specimens have been monitored for as long as 6 weeks, and have shown a reasonable quantity of resin still in place on the cement. In view of the prolonged chemical maturation that occurs with glass-ionomer cements, the continued presence of the resin is desirable.

It should be noted that if a new restoration less than 6 months old is to be exposed to dehydration for longer than a few minutes, it is desirable to protect it again with a further layer of unfilled resin bond. After 6 months, the cement is generally mature enough to withstand such stress (Figure 1.30).

The only problem arising from the use of such a long-lasting sealant is that, with a Class V restoration, an artificial overhang may be created and, with a Class III restoration, the contact area may be closed by the resin. Both situations should be anticipated and appropriate precautions taken. An overhang can be removed at the time of placement by using a sharp blade to cut away from the restoration towards the tooth (Figure 1.31). A closed contact can be re-opened later at the polishing appointment, if the patient has been unable to remove the resin. Mostly, the patient will succeed in restoring freedom.

Most manufacturers maintain that their aesthetic restorative auto cure glass-ionomer cement can be contoured and polished at approximately 10–15 minutes after placement. Certainly, the cement will have achieved a degree of set such that polishing can be carried out, but only at the sacrifice of translucency and aesthetics. Both water uptake and water loss within the first 24 hours will downgrade the physical properties and appearance of all these cements, and it is well worth while delaying the final finish for at least a day—preferably a week—if optimum results are required (Figures 1.32–1.35).

Some manufacturers provide a very low-viscosity resin sealant for their dual cure cements—not to control water exchange but to seal the surface porosities. The concept is sound in as much as the surface, following contouring and polishing, will be rather porous and slightly rough. The very low-viscosity resin may seal the surface and make the restoration smoother. However, care must be taken to ensure there is no overhang left behind.

It has been suggested in the past that it is necessary to cut a shallow finish line along the incisal margin of a Class V erosion lesion because the cement is likely to 'ditch' along that margin if left in thin section. However, providing the cement is protected as suggested with a completely waterproof sealant and is thus allowed to mature fully, then the cement will survive satisfactorily even though in thin section (Figure 1.34).

The chemistry of the fast-setting Type I, Type II reinforced and Type III cements has been modified to the extent that they are relatively resistant to water uptake within 5 minutes of the start of mix. They are, however, still subject to dehydration for up to 2 weeks after placement. If left exposed for 10 minutes, they will visibly crack and craze, and attachment to enamel and dentine will fail. If, for example, a quadrant of cavities has been exposed under rubber dam and glass-ionomer cement is to be used as a lining, the teeth should be restored one at a time. The lining should be placed and, as soon as it is set, covered with the final restoration. If a Type II reinforced cement is to be used as the restoration then it should be protected against dehydration with an unfilled resin bond while the remaining restorations are being placed. Once the cement is covered or is immersed in saliva, it is safe from further dehydration (see Figure 4.27).

The corollary to this rapid-setting mechanism is that the Type II.2 reinforced restoration can be

completed all the way to a final polish, beginning 6 minutes after the start of mix. Once the initial set is achieved, it can be contoured and polished to a very fine surface, using ultra-fine diamonds followed by graded rubber polishing points under air/water spray, taking care not to dehydrate.

Adhesion to enamel and dentine

A diffusion-based adhesion can be obtained between the cement and the dentine or enamel. Wilson has described an ion-exchange layer that is visible under the scanning electron microscope and represents the chemical union between the two. He suggests that the poly(alkenoic acid) attacks and penetrates the tooth structure, displacing phosphate ions. To maintain electrolytic balance, it is necessary that each phosphate ion take with it a calcium ion. These are taken up into the cement adjacent to the tooth, and produce an ion-enriched layer that is firmly bound to both enamel and dentine. The strength of both the ion-enriched layer and its union to the tooth have yet to be measured.

Because of the relatively low tensile strength of the cement, failure of the union will normally occur within the cement rather than at the interface between the cement and the tooth, so that the stronger the cement, the better the adhesion (Figures 1.36–1.42). This presupposes, however, that the interface is clear of debris such as saliva, pellicle, plaque, blood and other contaminants (Figures 1.43–1.45). In the clinical situation this can be achieved by conditioning the cavity surface with a brief application of 10% poly(acrylic acid). This is a relatively mild acid that will dissolve the smear layer within 10–15 seconds, although if left for longer than 20 seconds, it is likely to begin to demineralize remaining dentine and enamel and open up dentinal tubules. There are two additional advantages in using this particular material for conditioning the dentine. Firstly, since it is the acid utilized in the cement itself, any residue inadvertently left behind will not interfere in the setting reaction, and, secondly, it will enhance the wettability of the tooth surface and pre-activate the calcium and phosphate ions in the dentine and render them more available for ion exchange with the cement (Wilson and McLean, 1988).

If chemical union is to be relied upon to retain the restoration in a Class V erosion cavity, it is recommended that the surface of the tooth be cleaned first with a slurry of pumice and water (Figures 1.46–1.48). Note that most proprietary polishing pastes will leave a smear layer behind, so plain pumice and water is preferred. The surface should now be conditioned with 10% poly(acrylic acid) for 10–15 seconds only. This will remove any remaining debris and pre-activate the calcium ions in the dentine (Figures 1.49 and 1.50). No cavity preparation is required. On the other hand, if chemical adhesion is not required, as with a lining under amalgam or gold, then conditioning the dentine is an unnecessary step.

It should be noted that an alternative to removing the smear layer is to apply a mineralizing solution, such as Causton's ITS solution (see Box B, page 26) or 25% tannic acid, which will tend to unite the smear layer to the underlying dentine and enamel and seal over dentinal tubules. This is the recommended technique when using glass-ionomer cement as a luting agent for full crowns. Considerable hydraulic pressure may be generated during the seating of crowns, and it is better to seal the tubules rather than open them up prior to placement. A 2-minute application of either Causton's ITS solution or 25% tannic acid will offer protection and help to prevent post-insertion sensitivity.

Fluoride release

As with silicate cement, fluoride is used as a flux during the manufacture of the glass powder, and it is then incorporated within the glass in the form of extremely fine droplets. Some fluoride is available from the powder particles themselves, but there is a considerable release following mixing with poly(alkenoic acid). The initial peak may be quite high, but the flow will decline fairly rapidly over the next 2–3 months to finally stabilize at a low but steady level (Figure 1.51). Maintenance of this level has now been monitored for at least five years without a significant decline (Forsten, 1993). The dual cure cements appear to follow the same pattern, but of course they have not yet been monitored over the same length of time. Since the fluoride is not a part of the matrix of the cement, the fluoride

(*contd p. 26*)

Figure 1.32

Class V restoration on the upper-left canine immediately after placement. Note the relative lack of translucency.

Figure 1.33

The same restoration following polishing, 1 week after placement. There is an improvement of colour match and translucency.

Figure 1.34

Class V erosion lesions in the upper left canine: first and second bicuspids were restored five years previously and protected with a resin-bonding agent. The restorations have not been polished at all and have retained the original surface from the matrix. Note also that, even though a finish line was not cut in the dentine along the incisal margin, the excess 'flash' remains intact.

Figure 1.35

Class V glass-ionomer cement restoration in a group of upper anteriors, extending from the left-central incisor to the right canine, about 4 years after placement, showing complete maturity and stability.

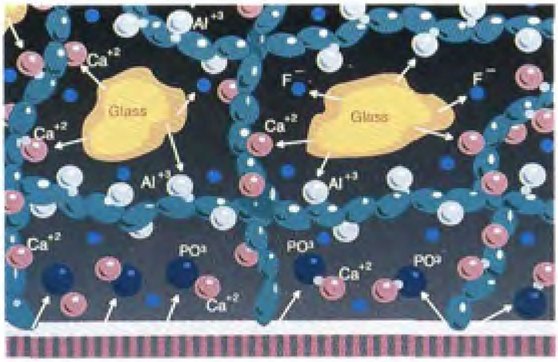


Figure 1.36

A theoretical diagram showing the development of the ion exchange between the cement and the tooth surface. Note that the poly(alkenoic acid) chains actually penetrate the surface and displace phosphate ions, releasing them into the cement. Each phosphate ion takes with it a calcium ion to maintain electrolytic balance, thus leading to an ion-enriched layer.

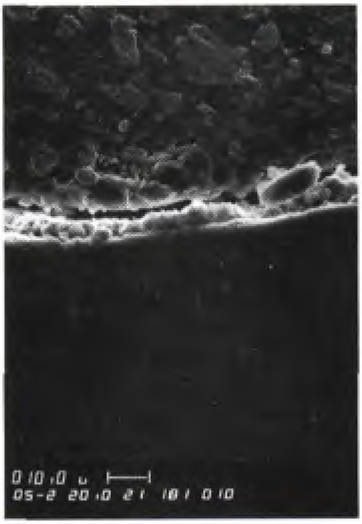


Figure 1.37

SEM showing the ion-exchange layer between the glass-ionomer cement and the dentine. The layer is firmly adherent to the dentine, and separation has occurred in the cement due to dehydration during preparation of the specimen for the SEM. *Original magnification* × *500.*

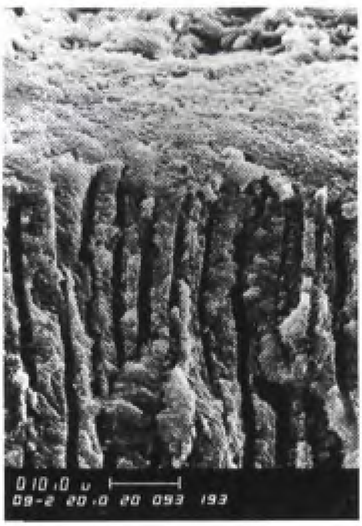


Figure 1.38

SEM showing the ion-exchange layer remaining on the dentine after complete loss of the cement. *Original magnification* × *900.*

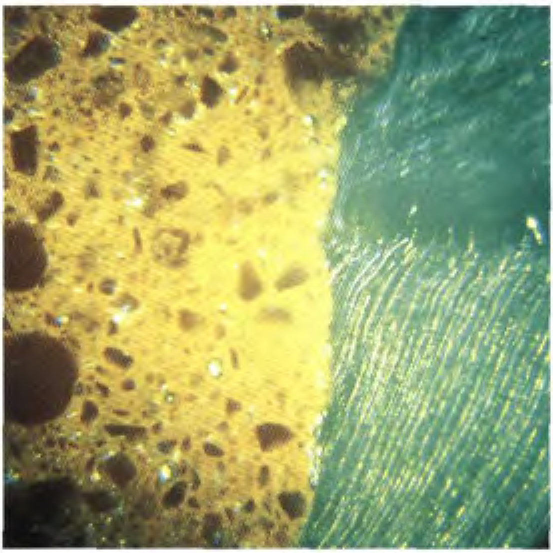


Figure 1.39

The union between glass-ionomer cement and both enamel and dentine examined through a confocal optical microscope. This technique does not require dehydration of the specimen before viewing, and therefore there are no artefacts present such as occur when preparing a specimen for viewing under a scanning electron microscope. Note the intimate union between the three materials: enamel top right, dentine bottom right and cement on the left. (Courtesy of Dr TF Watson.)

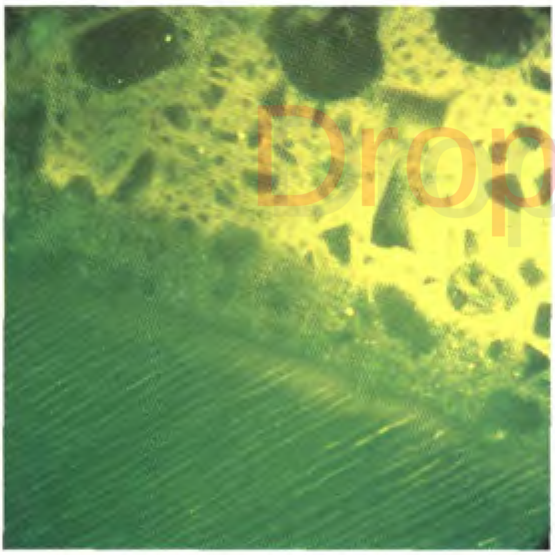


Figure 1.40

The union between glass-ionomer cement and dentine viewed under a confocal optical microscope. Rhodamine B was added to the water used to rehydrate the cement. Examination of the interface between the cement and the dentine now reveals fluorescent dye uptake into both the dentine and the cement, possibly confirming the ion exchange between the two. (Courtesy of Dr TF Watson.)

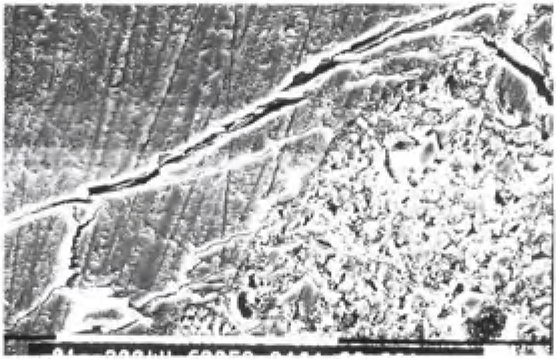


Figure 1.41

SEM showing the union between a dual cure cement and dentine. Note that in this specimen there has been some separation in the dentine rather than at the ion-exchange layer, presumably because of the increased tensile strength of this cement. *Original magnification × 1000.*

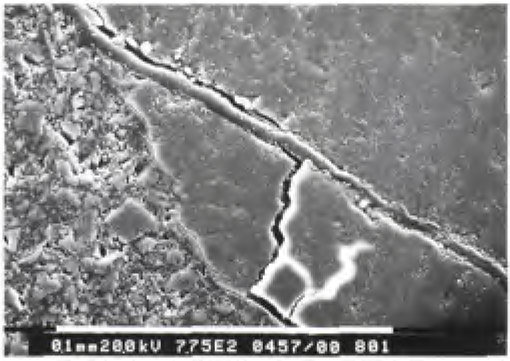


Figure 1.42

SEM showing the union between a dual cure cement and enamel. As in Figure 1.41, there is some separation in the enamel—presumably for the same reason. *Original magnification × 1000.*

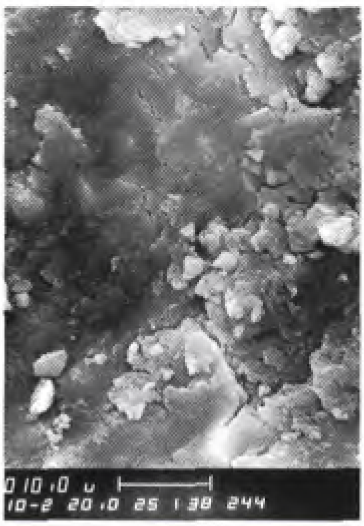


Figure 1.43

SEM showing the smear layer left on the dentine surface following cavity preparation at slow speed. Note that in the oral cavity there will be an admixture of plaque, pellicle, saliva and blood. If the ion-exchange layer is to be developed (Figure 1.37), the smear layer should be removed. *Original magnification × 1000.*

Figure 1.44

Dropper bottle used for the application of 10% poly(acrylic acid). The lumen occasionally may be occluded by the acid setting in it, but can be washed out.

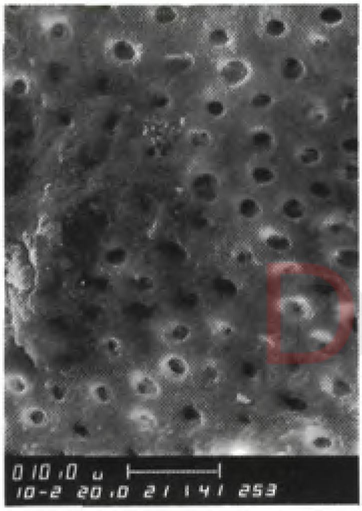


Figure 1.45

SEM showing the surface of the dentine after a 10–15-second application of 10% poly(acrylic acid). Note that many of the dentine tubules are still occluded but the surface is relatively clean. *Original magnification* × *900.*

Figure 1.46

SEM showing the surface of an erosion lesion prior to cleaning. The accumulation of plaque will inhibit the development of the required ion-exchange layer. *Original magnification* × *900.*

Figure 1.47

Slurry of pumice in water. This is the preferred material for removing plaque from the surface of an erosion lesion.

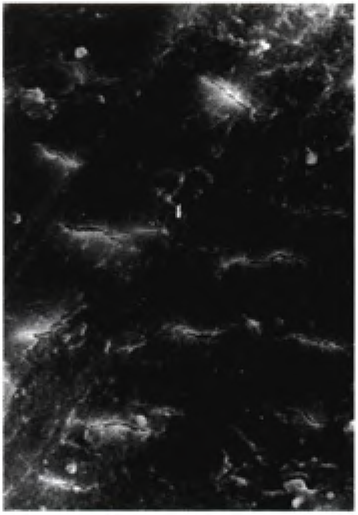


Figure 1.48

SEM of an erosion lesion after cleaning with a slurry of pumice in water for 5 seconds. Note that generally all the dentinal tubules are closed over by burnished dentine. *Original magnification* $\times$ *900.*

Figure 1.49

Cleaning an erosion lesion with a slurry of pumice in water.

Figure 1.50

Conditioning the surface with 10% poly(acrylic acid), following cleaning. The area should be washed thoroughly after 10–15 seconds.

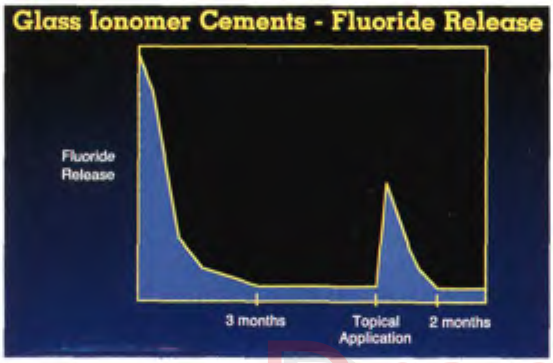


Figure 1.51

A graph showing the release of fluoride over time from an average glass-ionomer cement (after Forsten). The steady level of release has now been observed over 5 years. Note the possibility for fluoride uptake following a professional topical fluoride application.

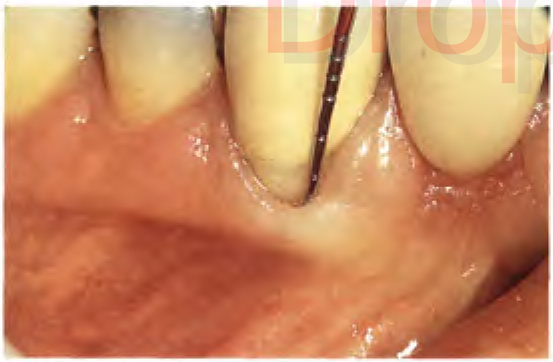


Figure 1.52

An erosion lesion at the gingival margin of the crown on the lower-right first bicuspid was repaired with glass-ionomer cement approximately 5 years ago. The gingival margin of the cement is 2 mm, within the gingival crevice. Note the excellent condition of the gingival tissue lying over the cement because of the resistance to plaque build-up resulting from the fluoride release.

Figure 1.53

Class V glass-ionomer cement restorations on the lingual of the lower-left lateral and canine. There is an accumulation of calculus and plaque on the adjacent teeth. However, presumably because of the fluoride release, there is a relative lack of plaque accumulation on the cement.

BOX B CAUSTON'S ITS SOLUTION

The following is the formula for the mineralizing solution recommended for attaching the smear layer onto the dentine and sealing dentinal tubules. This solution can be made up by a pharmacist and is chemically stable for 18 months and longer.

Component	g/litre
$CaCl_2$	0.20
KCl	0.20
$MgCl.6H_2O$	0.05
NaCl	8.00
$NaHCO_3$	1.00
$NaH_2PO_4.H_2O$	0.05
Glucose	1.00

Adapted from Causton BE, Johnson NW, Improvement of polycarboxylate adhesion to dentine by the use of a new calcifying solution, *Br Dent J* (1982) **152**:9–11.

release is not deleterious to the physical properties. It has been suggested that there is, in fact, a fluoride exchange available, with fluoride ions returning to the cement from external applications of fluoride at a later date if the fluoride gradient is in the right direction. Thus topical fluoride and the use of a fluoride toothpaste may provide a 'topping-up' effect (Figure 1.51).

In the presence of continuing fluoride release, plaque is less likely to accumulate on the surface of the restoration (Figure 1.52), and, since there is no microleakage at the margin, both tissue tolerance and colour stability are of a very high order (Figure 1.53).

Soft tissue tolerance

The soft tissues of the oral cavity as well as the dental pulp demonstrate a very high level of tolerance to the presence of glass-ionomer cement. The poly(alkenoic) acids of the system are relatively mild acids with long and complex molecular chains, which will not readily penetrate dentine tubules, and the dentine itself is a very effective buffer to acids in general. Also, when reacted with the glass powder, the toxicity of the poly(alkenoic) acids is still further reduced. Derivatives from the glass-ionomer cements are now used in surgery as bone replacements, and it has been shown that soft tissues adapt very intimately to the cement.

Studies of the dental pulp have shown that there may be a very mild inflammatory response to the presence of freshly mixed glass-ionomer cement, followed by a rapid recovery over a period of a few days. Recent work has shown dentine bridging over a mechanical exposure created in an otherwise healthy pulp (C.W. Cox, Alabama, personal communication).

It has been accepted for some years that pulpal irritation is the direct result of bacterial activity only, so if there are no bacteria present there will be no inflammation. Lining materials are not expected to provide a therapeutic effect on the pulp, but if they provide a complete seal then bacterial activity cannot progress. This suggests that glass-ionomer cement, through its ionic union with tooth structure, will be an ideal sealant for a cavity, preventing the ingress of bacterial nutrients and reducing any that may be present to a spore form.

It is suggested, therefore, that glass-ionomer cement can be placed in close proximity to the *pulp without the risk of developing an irreversible* pulpal inflammation, and the laying down of a further sub-lining under this cement is not justified. Furthermore, softened, affected, demineralized dentine can be safely left under a glass-ionomer restoration, providing the margin is completely sealed around its full circumference.

Other researchers have shown an almost complete inhibition of the growth of *Streptococcus mutans* on the surface of glass-ionomer cement along with a reduction in the growth of many other bacterial species. This is postulated to be because of the presence of the fluoride release, and can be readily confirmed by observation in the oral cavity. The free fluoride ions will also be taken up into adjacent tooth structure and modify the surface wettability, thus further reducing the ability of plaque to grow in that vicinity. It is not possible to develop a smooth glossy surface on the cement, but nevertheless bacterial plaque fails to thrive to the extent that restorations that are subgingival will not irritate the gingival tissues and take up very little stain (Figures 1.52 and 1.53).

Physical properties

Work is in progress on improving the physical properties of glass-ionomer cements, and it is anticipated that the next generation will extend the clinical applications of this group of materials quite markedly. Theoretically, flexural strength can be improved by the inclusion of a disperse phase, and this has been tried but is not yet clinically proven. Amalgam alloy particles have been added, but, since there is no union between the metal and the cement, physical properties remain virtually unaltered. The inclusion of very finely powdered pure silver particles, which are sintered to the surface of the glass powder, has been shown to produce a notable improvement in abrasion resistance. However, other physical properties are only moderately improved and, in fact, adhesion to dentine and enamel may be slightly reduced.

The inclusion of additional resins in the dual cure cements has led to an improvement in compressive and tensile strength, as demonstrated in the shear/punch test, to the point where the strength of the glass-ionomer cements is coming close to that of the micro-filled composite resins (see Figures 1.6 and 1.7). However, they are still not capable of rebuilding *a marginal ridge or an incisal corner.*

Variations to the basic constituents of the glass-ionomer cements are being subjected to experimentation and increases in physical properties may result. However, the essential elements of this group of cements will always be the ionic bond available between the cement and tooth structure through the presence of poly(alkenoic acid), as well as the fluoride release. Inclusions in the formula that reduce the effectiveness of the poly(alkenoic acid) or, indeed, eliminate the acid entirely will remove that cement from this highly successful group of restorative materials. The non-glass-ionomer cements discussed on pages 4 and 7 fall into this category, and, in spite of apparently greater physical properties in some of the materials, they should not be confused with true glass-ionomer cements.

Fracture resistance

At the present stage of development, the physical strength of the material is sufficient to withstand moderate occlusal load, provided it is well supported by surrounding tooth structure. It is not recommended for rebuilding cusps or marginal ridges to any extent, particularly in the patient who is likely to exert heavy occlusal stress. Resistance to tensile and shear stresses is such that it should not be relied upon as sole support for a crown, for example. The Type II.2 restorative reinforced version is valuable as a core build-up because it is possible to proceed immediately to the final preparation of the tooth. However, the cement requires considerable support itself from remaining tooth structure (Figure 1.54).

Figure 1.54

Core build-ups using a cermet cement on two upper-right bicuspids. There is still sufficient natural tooth structure left to accept the occlusal load, thus compensating for the relative lack of tensile strength in the cement.

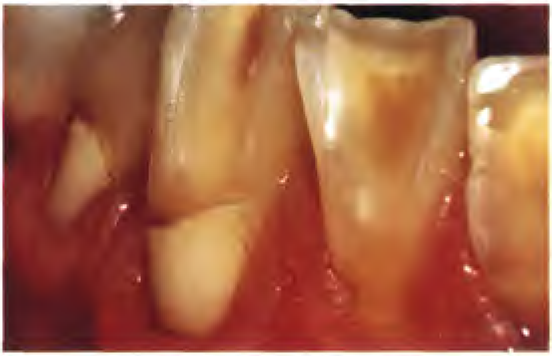


Figure 1.55

Three lower anteriors in a patient with a very deep overbite. Considerable abrasion has removed all the enamel, and subsequently the dentine has been subjected to erosion. As there was sufficient space available, glass-ionomer cement restorations were placed on all three, but they all failed because of the extreme shear stresses. The only surviving cement is the gingival section on the canine, which was beyond the incisal edge of the opposing canine and therefore free of direct stress.

Resistance to shear stress is not good. For example, although it has an excellent record for the restoration of erosion lesions, it will not be retained on the labial surface of lower anterior teeth that have been abraded through a deep overbite and then suffered further erosion. Although there is room for the cement without interfering with the occlusion, the shear stresses are too great (Figure 1.55).

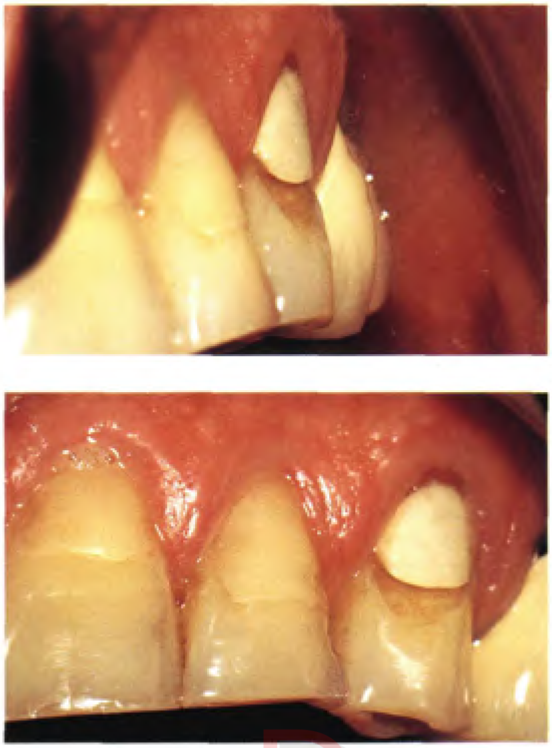
Abrasion resistance

The degradation of the material in the oral cavity has yet to be studied fully, but longevity studies suggest that a well-placed glass-ionomer cement will stand heavy abrasion better than remaining tooth structure, provided that the powder/liquid ratio is high enough (Mount, 1986) (Figure 1.56). The presence of finely powdered silver particles on the surface of the glass, as in the Type II.2 restorative reinforced cement, will increase abrasion resistance to the stage where it is similar to amalgam and composite resin.

In the laboratory the dual cure cements appear to demonstrate a similar resistance to abrasion. However, this is the one property that cannot be adequately reproduced out of the oral cavity, so a decision will only be made over time.

Dimensional stability

The auto cure cements show a limited degree of setting shrinkage (up to 2–3%) over a short period



a

b

Figure 1.56

(*a*) Class V ASPA restoration in an upper-left canine, 12 years after placement. There is further erosion in the tooth structure beyond the cement restoration. Despite the rather poor quality cement, it has maintained its contour well. (*b*) Same restoration as (*a*). The restorations in the central and lateral incisors have been in place for 4 years.

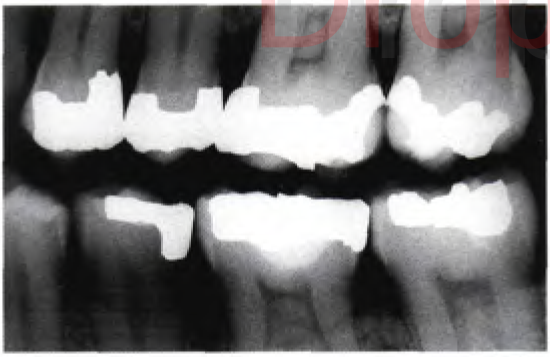


Figure 1.57

Tunnel restorations in the upper-right first and second molars using a cermet cement show radiopacity very similar to amalgam.

Figure 1.58

A bitewing radiograph of dual cure restorations in upper and lower first deciduous molars, showing contrast with tooth structure sufficient to allow future monitoring of the restoration.

BOX C POLISHING METHODS

Type II.1 restorative aesthetic

Dual cure

- Contour and polish immediately after light activation, working from restoration to tooth only.
- Begin with fine polishing diamonds at intermediate high speed (40 000 revolutions/min) under air/water spray.
- Continue with ever-finer diamonds at lower speeds, still under air/water spray.
- Finally complete using aluminium oxide graded polishing discs at slow speed under air/water spray, then seal with a low-viscosity resin glaze.

Auto cure

- Because of the slow-setting chemistry, do not attempt to contour or polish the cement for at least 24 hours.
- Gross contour can be achieved with very fine sintered diamonds under air/water spray at 20 000 revolutions/min.
- Refine the surface with graded rubber polishing points and cups at 5000 revolutions/min under air/water spray.
- Finish to a gloss with graded polishing discs at 3000 revolutions/min under air/water spray, then seal with a low-viscosity resin glaze.

Type II.2 restorative reinforced

- Because of the rapid-setting chemistry, these cements can be contoured and polished beginning at 6 minutes from the start of mix.
- Gross contour can be achieved with very fine sintered diamonds under air/water spray at 20 000 revolutions/min.
- Refine the surface with graded rubber polishing points and cups at 5000 revolutions/min under air/water spray.
- Interproximal surfaces can be contoured and polished with the Profin Directional System equipment using diamond or polishing blades.

A selection of polishing cups and points, finishing and polishing discs.

A selection of graded fine diamond polishing stones. Note the colour coding from moderately coarse to extra fine, allowing for rapid development of a fine surface.

of time. However, because it is a chemical set, the shrinkage will occur inwards toward the cavity floor and the ion-exchange union with the tooth structure will not be subjected to undue stress. Subsequent water uptake will compensate for the shrinkage and the restoration will stabilize over the next week or so after placement.

The situation is modified by the inclusion of additional resins in the dual cure cements, particularly the inclusion of HEMA which is very hydrophilic. The acid/base reaction will begin as the cement is mixed and the ion-exchange mechanism with the tooth will commence immediately the cement is placed into the cavity. The application of the activator light, however, will bring about an immediate setting reaction in the resin component of the cement with a shrinkage up to 1%. Since the extra resins represent less than 5% of the total restoration the shrinkage is not expected to direct undue stress on to the chemical union with the tooth. The acid/base reaction will then continue at a somewhat reduced rate and the 'dark cure' phase of the setting mechanism of the additional resins will reach completion within a short period of time.

The early dual cure lining cements showed a considerable water uptake over 90 days with an increase in volume and a reduction in physical properties. The restorative dual cure cements, however, show a very small water uptake over the same period of time and maintain their physical strength very well. The increase in volume is in the order of 3% and is of no clinical significance.

Radiopacity

It is desirable that an interproximal restoration in a posterior tooth be able to be differentiated radiographically from dentine or recurrent caries so that changes can be reliably monitored. These cements can be made radiopaque through the selection of an appropriate glass or the inclusion of radiopacifiers such as barium sulphate or metals such as silver. Generally the radiopacity of the dual cure cement comes from the glass and comfortably exceeds that of dentine. The colour and translucency are not affected, so they can be placed universally even if monitoring with X-rays is not appropriate (Figures 1.57 and 1.58).

The original auto cure Type II.1 cements are generally radiolucent, and the inclusion of radiopacifiers tends to modify the colour, so they are not recommended for the restoration of cavities where monitoring with X-rays is required.

Polishing

The process of producing a fine surface on any restorative material is one of reducing the depth of the scratches that have developed during recontouring. With the glass-ionomer cements, the smoothest surface will be that developed under the matrix. The surface will be mildly porous and matrix-rich, with very few glass particles showing and, prior to full maturity, very susceptible to damage. As far as possible, particularly early in the life of the restoration, any reshaping should be kept to a minimum and the surface developed by the matrix should be maintained.

All the fast-setting cements, including the dual cure cements, can be trimmed and contoured as soon as they are set. Gross contour can be modified using a sharp blade moving only from the restoration to the tooth to avoid stressing the newly forming ion-exchange layer. Any additional contouring should be carried out with rotary instruments, beginning at intermediate high speed (20 000–40 000 revolutions/min) and reducing the speed with the finer instruments. Always work under air/water spray to avoid dehydration.

Initially, particularly with the dual cure cements, use fine graded diamond polishing burs, beginning with the relatively coarse stones and changing to finer ones for a better finish. The ultimate surface can be developed with fine graded aluminium oxide discs, still under air/water spray. The quality of the finished surface will depend in part on the glass particle size of the cement and in part on the degree of porosity. Inevitably the cement will be porous because it is a two-part mixed material. Generally capsulated machine-mixed cements show many fine porosities, while hand-mixed ones have fewer but larger defects.

Application of a very low-viscosity resin glaze over the final surface will fill the porosities and leave an even better surface, but care must be taken not to leave an excess of glaze and so forming a ledge or overhang.

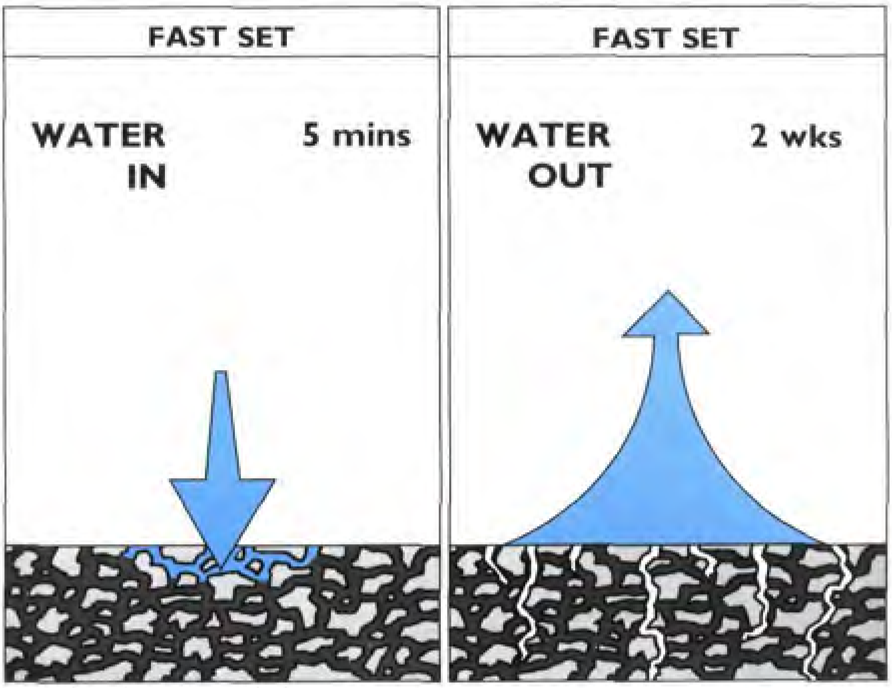


Figure 2.2

Diagram showing the water balance of the Type I glass-ionomer cements. Note that they are resistant to water uptake within about 5 minutes of the start of mix, but remain subject to water loss for about 2 weeks after placement.

of crowns and bridges, and it is reasonable to question the need to replace them. They are apparently safe to use and relatively insoluble, and last many years. The zinc polycarboxylate cements were developed in the middle 1960s and offered the possibility of adhesion to both tooth structure and noble metals. However, their tensile strength was low, and therefore the promised adhesion was relatively short-lived.

The glass-ionomer cements also show adhesion to tooth structure, but their tensile strength is no greater than the zinc phosphate cements. Therefore they cannot be used to retain a casting that does not demonstrate a good firm fit in the first place. Shortcomings in design cannot be compensated by an 'adhesive' cement as long as the tensile strength of the cement is low. The question then is why one should use a glass-ionomer cement instead of a zinc phosphate one.

The following factors are in favour of glass-ionomer cement:

- The tensile strength of both cements is similar.
- The solubility of glass-ionomer cement is significantly lower.
- The thixotropic flow properties of the glass-ionomer cement allow for easier placement of the prosthesis without the need to retain pressure during setting.
- It is easier, therefore, to achieve an acceptable ultimate film thickness.
- The potential for post-insertion sensitivity is the same for both cements.
- There is the potential for an ongoing fluoride release with the glass-ionomer cement.

When comparing glass-ionomer and zinc phosphate cements with resin cements, the following factors should be taken into account:

- With the resin cements mechanical adhesion with underlying tooth structure may be available following etching of the dentine.

2 Type I: Luting cements

Description

The chemistry of the luting cements is essentially the same as the others in this group of materials. However, the size of the powder particles is finer, to ensure achievement of an ultimate film thickness at an acceptable level. This involves compromise in that, with the finer particle size, working and setting times are reduced but physical properties are improved. Flow properties are such that placement of a restoration to its full extent is relatively easy and, unlike the zinc phosphate cements, it is unnecessary to maintain positive pressure on the restoration during the setting period (Figure 2.1).

Unlike the zinc phosphate cements, it is not possible with the luting cements to vary the setting time to any extent. With the former, chilling the slab and adding the powder in small increments gives the clinician some degree of control of working and setting times. However, the viscosity is somewhat higher in the first place, and it is necessary to maintain positive pressure after placement to ensure that the appliance does not lift off the tooth before the cement is set. Under these circumstances, venting a crown is desirable.

With the glass-ionomer cements, there is a rapid 'snap' set, whether the slab is chilled or not and regardless of the rate at which the powder is incorporated into the liquid. Increase in viscosity and achievement of a snap set varies between products, and the anhydrous types tend to allow longer working time before becoming too viscous to permit full placement of the restoration (Figures 2.3 and 2.4).

Reasons for use

The zinc phosphate cements have now been in general use for many years for the cementation

Figure 2.1

A porcelain-bonded-to-metal crown that was removed about 2 years after placement because of loss of porcelain. It has been cut in two to show the cement still attached to the gold rather than to the tooth. Note also the even layer of cement over the entire surface, although the crown was not vented.

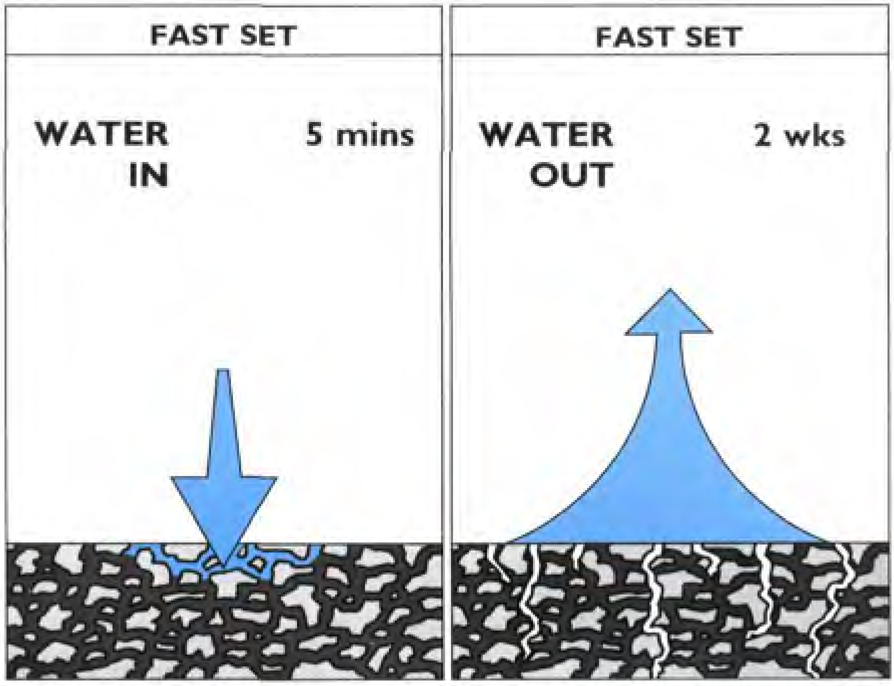


Figure 2.2

Diagram showing the water balance of the Type I glass-ionomer cements. Note that they are resistant to water uptake within about 5 minutes of the start of mix, but remain subject to water loss for about 2 weeks after placement.

of crowns and bridges, and it is reasonable to question the need to replace them. They are apparently safe to use and relatively insoluble, and last many years. The zinc polycarboxylate cements were developed in the middle 1960s and offered the possibility of adhesion to both tooth structure and noble metals. However, their tensile strength was low, and therefore the promised adhesion was relatively short-lived.

The glass-ionomer cements also show adhesion to tooth structure, but their tensile strength is no greater than the zinc phosphate cements. Therefore they cannot be used to retain a casting that does not demonstrate a good firm fit in the first place. Shortcomings in design cannot be compensated by an 'adhesive' cement as long as the tensile strength of the cement is low. The question then is why one should use a glass-ionomer cement instead of a zinc phosphate one.

The following factors are in favour of glass-ionomer cement:

- The tensile strength of both cements is similar.
- The solubility of glass-ionomer cement is significantly lower.
- The thixotropic flow properties of the glass-ionomer cement allow for easier placement of the prosthesis without the need to retain pressure during setting.
- It is easier, therefore, to achieve an acceptable ultimate film thickness.
- The potential for post-insertion sensitivity is the same for both cements.
- There is the potential for an ongoing fluoride release with the glass-ionomer cement.

When comparing glass-ionomer and zinc phosphate cements with resin cements, the following factors should be taken into account:

- With the resin cements mechanical adhesion with underlying tooth structure may be available following etching of the dentine.

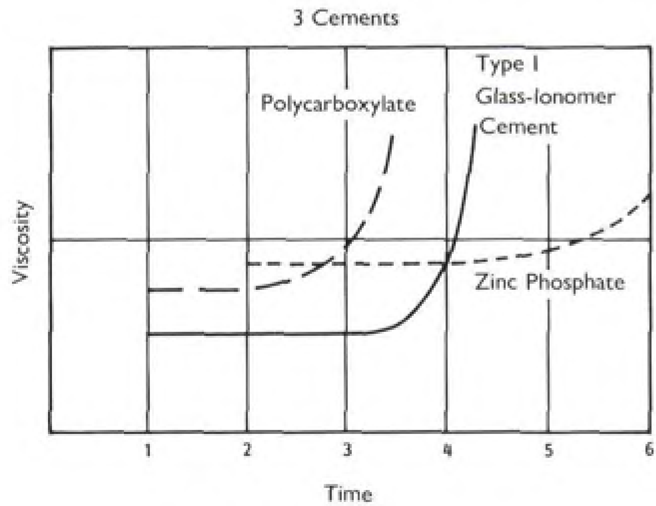


Figure 2.3

Comparison of development of viscosity of freshly mixed cements and ability to allow complete seating. Note that zinc phosphate cement is initially more viscous but allows seating for longer than the glass-ionomers. (Adapted from Øilo and Evje, 1986.)

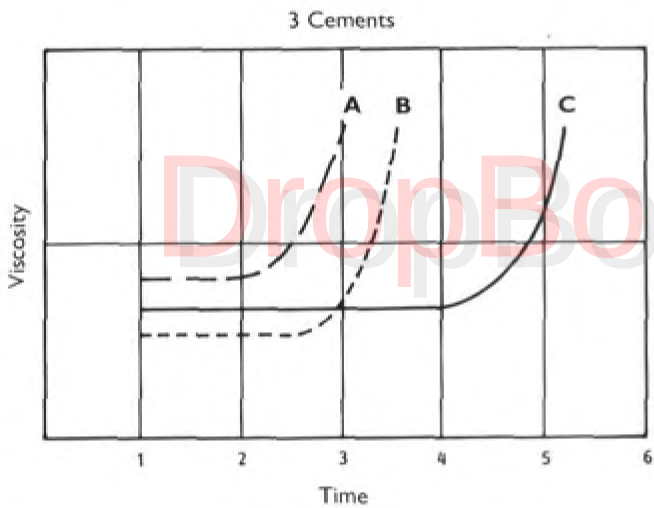


Figure 2.4

Rapid development of viscosity in glass-ionomer cements. All glass-ionomer cements tend to a 'snap' set once the viscosity begins to rise, so working time is not great. (Adapted from Øilo and Evje, 1986.)

A A cement containing dehydrated poly(acrylic acid) in the powder and using water as the liquid

B A cement which uses poly(acrylic acid) as the liquid

C A cement containing dehydrated poly(maleic acid) in the powder and using dilute tartaric acid as the liquid.

- The tensile strength of the resin cements is greater than that of the other two.
- The effect of long-term hydrolytic breakdown with the resin cements is not yet fully explored.
- Pulp compatibility of the resin cements is not yet fully explored.
- Ultimate film thickness with the resin cements is unacceptable.
- There is no fluoride release with the resin cements.
- The resin cements are essentially insoluble.

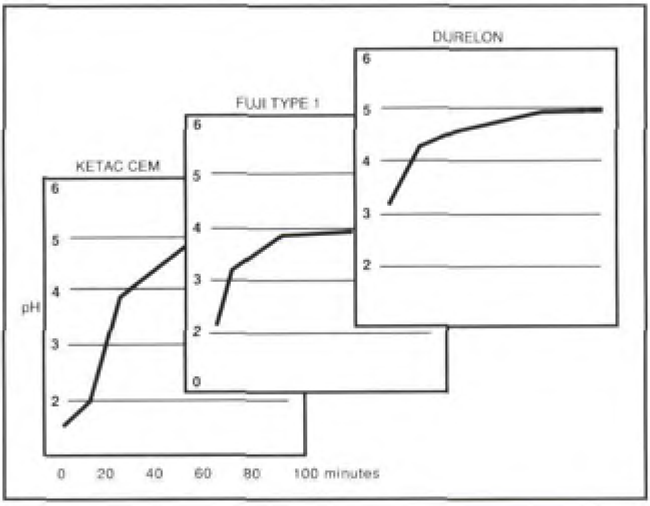


Figure 2.5

The initial pH of luting cements is rather low at the time of mix. However, all three types rise quite rapidly following insertion of the prosthesis. (Adapted from Charlton et al, 1991.)

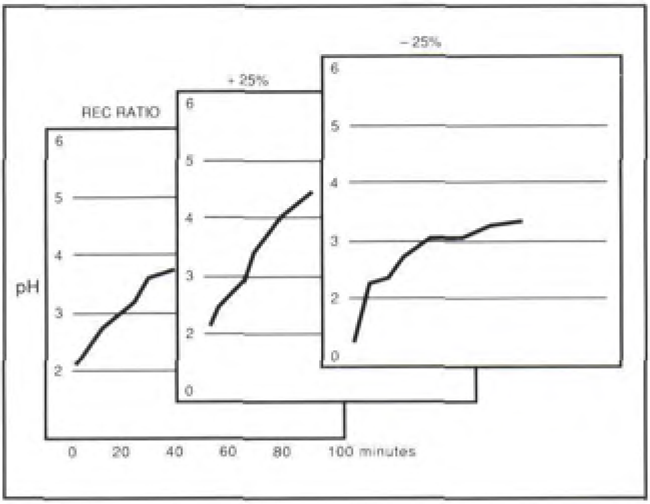


Figure 2.6

The powder/liquid ratio has a bearing on the speed at which the pH rises. A 25% reduction in powder content leaves the pH low for longer, thus increasing the risk of post-insertion sensitivity. (Adapted from Charlton et al, 1991.)

Significant factors

Powder/liquid ratio

Powder/liquid ratio is generally about 1.5 : 1. A moderate increase in powder content is acceptable, although this may reduce the working time and, if increased too far, will give unacceptable ultimate film thickness. Reduction of the powder content by 10% will reduce ultimate physical properties to a significant degree and may prolong the setting time. The pH of the newly mixed cement is normally quite low—approximately pH 1.8—but with the standard mix it will rise to pH 4.5 within the first 30 minutes. In the presence of a reduced powder content the pH will remain low for a prolonged period, resulting in a possible post-insertion sensitivity (Figures 2.5 and 2.6).

(contd p. 40)

Clinical application

Vital tooth

Figure 2.7

Cementation of crowns on three upper anterior teeth. The temporary crowns have been removed and remaining temporary cement gently taken off without scrubbing.

Figure 2.8

The teeth are washed only and *not* conditioned with poly(acrylic) acid so that the smear layer is retained. The surface can be sealed with ITS solution if there is a risk of post-insertion sensitivity (see Box B, page 26).

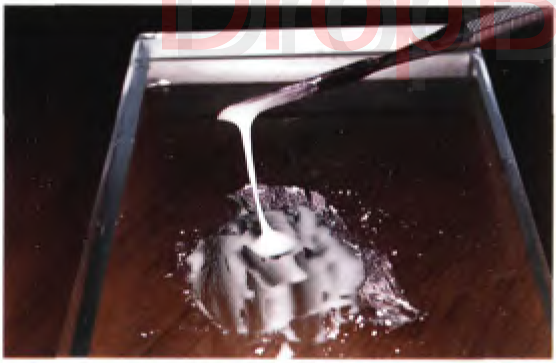


Figure 2.9

Mix the cement at the correct powder/liquid ratio to the correct consistency within 25 seconds. Do not over-spatulate. The cement should string up 2–3 cm from the slab before breaking and slumping back.

Figure 2.10

Apply cement to the inside of the crown with a fine bristle brush, making sure to paint the margins in particular.

Figure 2.11

Paint a small quantity of the cement onto the tooth.

Figure 2.12

Seat the crowns and apply firm positive pressure with an orange wood stick. Once the crowns are seated fully, there is no need to maintain pressure.

Figure 2.13

Wait until the cement is set to the stage where it cannot be indented with a sharp instrument, and immediately remove the excess from the margins. Do not delay, because the cement will continue to harden and become more difficult to remove.

Figure 2.14

Carefully remove all debris from within the gingival crevice.

Figure 2.15

The cemented crowns 1 week after insertion.

Non-vital tooth

Figure 2.16

Cementation of a post and crown on an upper-right lateral incisor. The temporary crown and post have been removed and the preparation cleaned.

Figure 2.17

The root face and posthole are conditioned with 10% poly(acrylic acid) for 10–15 seconds to remove the smear layer and enhance retention.

Figure 2.18

The area is washed thoroughly and dried with alcohol, paying particular attention to the apical end of the posthole.

Figure 2.19

Cement is mixed as required and a little painted onto the post.

Figure 2.20

Cement is wound into the posthole using an engine-driven Lentulo spiral or similar. The canal is filled to the top.

Figure 2.21

The post is positioned and adequate pressure applied to seat it using a wooden spatula. There is no need to maintain pressure.

Figure 2.22

The inside of the crown is painted with cement using a small, stiff-bristle brush.

Figure 2.23

The crown is positioned and pressure applied with a wooden spatula. There is no need to maintain pressure.

Figure 2.24

The finished crown about 6 months after cementation.

Dispensing in capsules and machine-mixing is the best method of control, and will ensure standard repeatable results. If mixing is to be carried out by hand, the working time can be extended to a limited degree by chilling the slab and the powder—but not the liquid—to a temperature just above the dew point.

Time to mature

Under many circumstances, the gingival margin of a restoration will be subgingival and so impossible to isolate during cementation. It is therefore desirable for luting cements to be fast-setting and to have high resistance to water contamination within 5 minutes of the start of mix. It is then unnecessary to seal the cement under a waterproof varnish or resin bond. It should be noted, however, that the cements remain subject to dehydration if left isolated for longer than 10 minutes from the start of mix. This means that water balance must be maintained by releasing the cement to the oral environment within that time.

Adhesion to enamel and dentine

It is possible to develop chemical adhesion to dentine and enamel, and it is also possible to gain a degree of adhesion to noble metals by coating the fitting surface of the restoration with a 2–5 μm layer of tin oxide. Of course, for restorations constructed by an indirect technique retention should be derived from the design of the preparation and the fine fit of the restoration. The luting cement should be present only to seal the

interface between restoration and tooth, and should not be relied upon to provide adhesion.

Cementation on vital teeth

In cementation of a full crown it is possible to develop considerable hydraulic pressure, so it is undesirable to open up dentinal tubules to any degree at all. Therefore conditioning the surface of the dentine and removing the smear layer with mild acids, such as 10% poly(acrylic acid), is contraindicated. If preparation of the dentine is desired then a solution such as Causton's ITS solution (see Box B, page 26) or 25% tannic acid should be applied for approximately 2 minutes prior to cementation. Either of these will seal the smear layer onto the surface and cover dentinal tubules.

An alternative is to apply the new generation of dentine-bonding agents which contain a poly(alkenoic acid), in particular maleic acid, because these will form a hybrid layer similar to the ionic exchange layer developed by glass-ionomer cement. The best time to apply the bond is subsequent to making temporary restorations and taking the final impressions, and immediately prior to cementation of the temporaries. The tubules will then be sealed during the temporary phase, with a reduction of sensitivity both at the time of cementation and subsequently.

Cementation on non-vital teeth

If the restoration is being placed on a non-vital tooth, development of optimum adhesion is possible. The remaining tooth structure should be conditioned with an application of 10% poly(acrylic acid) for 10–15 seconds to remove the smear layer, washed thoroughly and then dried with a light application of alcohol. The dentine should then be dried but not dehydrated, and the cement applied without further contamination.

Fluoride release

Fluoride release is available, but, in the light of the small quantity of cement present at the margin, it cannot be relied upon for remineralization of adjacent and surrounding tooth structure.

Pulp compatibility

There has been some controversy concerning possible adverse pulp response and post-insertion sensitivity when using some cements in this group. However, there is a high degree of compatibility between the cement and the pulp under normal circumstances, and the dentine is in itself a very efficient buffer against variations in pH levels. Recent surveys suggest that the incidence of sensitivity is not, in fact, greatly at variance with other cements, such as the zinc phosphate group. Generation of hydraulic pressure may complicate the response if the dentinal tubules have been opened up by removal of the smear layer. Therefore a vital tooth should not be conditioned prior to cementation. Alternatively, the surface may be sealed with Causton's ITS solution or 25% tannic acid for 2 minutes. Venting of full crowns is a further precaution that may assist in avoiding problems.

Physical properties

The physical properties have been shown to be equivalent to, or better than, the zinc phosphate cements, and the glass-ionomer cements are becoming the standard against which other cements are measured. Solubility is low, provided that the powder/liquid ratio is high enough, and compressive and tensile strength is adequate, because of the fine particle size.

Radiopacity is desirable so that cement residue can be detected in areas of difficult access.

3 Type II.1: Restorative aesthetic cements

Description

The glass-ionomer cements enjoy all the properties of the ideal restorative material except that they lack physical resistance to undue occlusal load. Colour matching can be satisfactory, and translucency is available, although it takes a few days to develop (see Figures 1.32 and 1.33). Adhesion to both enamel and dentine is available and biocompatibility is of a high order, which means that pulp irritation is not a problem. Fluoride release is a major advantage, and there have been no reports of microleakage or recurrent caries. Clinical handling is not particularly demanding, and long-term stability in the oral environment has been well proven.

This category of cements is now available in a dual cure form as well as the original auto cure form. The main difference is the addition of further resins and photo-initiators to the dual cure cements so that they can be light-cured on command immediately after placement in the cavity. This apparently has no untoward effect on the normal auto cure reaction, which continues as usual, but it does provide an immediate resistance to water uptake and water loss. There is clinical convenience in this because the restoration can be contoured and polished as soon as it is set.

The physical properties of the dual cure cements are generally better, with resistance to the shear/punch test being increased by up to 50% (see Figures 1.6 and 1.7). Translucency and colour matching are improved, and the fluoride release remains similar.

However, the original auto cure cements remain very useful, even though it is a little harder to achieve first-class results in the clinical environment. The main difficulty is that, to retain the best translucency, it is necessary to allow the cement to set slowly and to achieve full maturity before it is released into the oral environment. Methods of developing a fast-set cement such as removal of excess calcium ions from the surface of the glass particles or modification of the thermal history of the glass will reduce the ultimate translucency of the restoration, and are therefore unacceptable.

Some manufacturers claim that their Type II.1 cement is sufficiently mature at 15 minutes to accept contouring and polishing. The immediate effect of carrying out these procedures under air/water spray may not be noticeable, but in the long term the restoration will not develop full translucency and the result will be disappointing.

The answer lies in allowing the cement to mature under a waterproof sealant for a minimum of 24 hours before challenging the cement with the possibility of water exchange—either in or out. It is a simple clinical procedure to apply a sealant immediately after removing the matrix and then delaying polishing for 24 hours or more. The results fully justify the time involved.

There has been an unfortunate tendency lately to try to develop a restorative material that can be contoured and polished immediately after insertion. Apparently time is at a premium. However, it is suggested that it is always desirable to review any restoration at a later date to re-assess the occlusion, check the contour and see that the colour match is adequate. No material that sets through chemical activity will achieve maturity immediately, so it is preferable to allow time before looking to a final result.

The dual cure and auto cure cements are very similar in most aspects, and will therefore be discussed together.

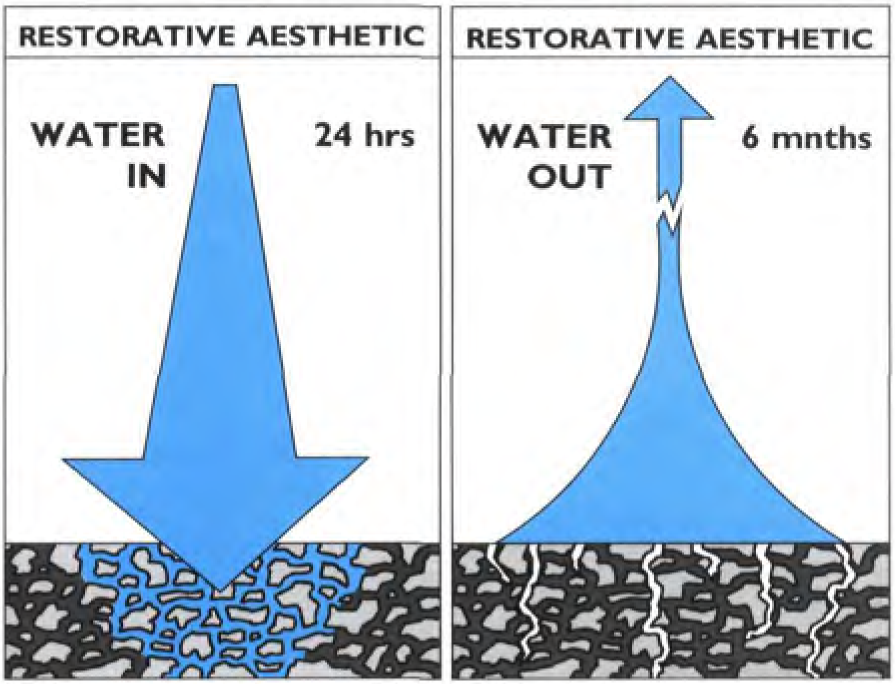


Figure 3.1

Diagram illustrating the water balance of the auto cure Type II.1 restorative aesthetic glass-ionomer cements. Note that water uptake is a serious problem in the early stages following placement. Water will penetrate through the entire depth of the cement very rapidly and downgrade both physical properties and, more importantly, translucency. It is also important to be aware of the potential of water loss for up to 6 months after placement.

Significant factors

Powder/liquid ratio

Powder/liquid ratio varies among the materials currently available, from approximately 2.9 : 1 to 3 : 1, for materials using hydrated poly(alkenoic acid) as the liquid, up to as high as 6.8 : 1, for one of the anhydrous types. The inclusion of the dehydrated poly(alkenoic acid) within the powder accounts for the increase. The proportions are similar for the dual cure cements. Within limits, the higher powder content leads to optimum physical properties. The translucency of the ultimate restoration is, to a large extent, related to the thermal history of the glass during manufacture, as well as to the fluoride concentration. The glass utilized in the restorative cements has a lower fluoride content, but, with the addition of tartaric acid in the liquid, the setting time remains clinically acceptable and translucency can be achieved with correct handling. A reduction in the

powder content may marginally increase translucency, but will at the same time lead to a deterioration in physical properties. Conversely, it is possible to increase the powder content to such a degree that not all the particles will be reacted, and this, of course, will result in a reduction of translucency and physical properties.

It is difficult to measure a standard quantity of both powder and liquid when attempting to mix by hand. There will also be incorporation of relatively large porosities during mixing, and placement into the cavity by hand will tend to aggravate the situation. It is possible to mix by hand and transfer the cement to a disposable syringe, but this is rather cumbersome and time-consuming, particularly since working time with these cements is generally relatively short.

Dispensing the powder and the liquid in a capsulated system that converts to a syringe is desirable, since the end result will be standard and predictable. Mixing time is reduced, but working time does not alter because there is a slight temperature increase during mixing. This temperature increase tends to encourage a snap set. Placement with a syringe will minimize incorporation of further voids, and the porosities will be relatively small and evenly distributed.

Time to mature

Dual cure cements

Immediately after light activation, the cement will be sealed to water exchange to the full depth of the light penetration. This will vary depending on the colour of the cement, the efficiency of the activator light and the length of time of light activation. Any remaining non-activated cement will continue to mature in a similar manner and at a similar speed as the auto cure cements. Probably both the glass-ionomer and the auto cure resin component will continue to mature for at least one week and maybe longer. This means that, particularly in a deeper cavity, care must be exercised early not to stress the developing ion-exchange union that is just beginning to form. Incremental build-up is always desirable.

Most manufacturers claim that a 20-second exposure to the light is sufficient, but often the light cannot be placed in close proximity to the restoration because of the presence of a matrix. As it is not possible to overexpose the restoration to the light activator, it is generally wise to allow a minimum of 40 seconds for a small restoration and longer for larger ones.

Some manufacturers offer a glaze to be painted over the finished restoration after polishing. This will have no effect on the continuing maturation, but will seal any voids or porosities exposed by the recontouring procedures and leave a smooth surface.

Auto cure cements

As discussed above, this group of glass-ionomer cements remains slow-setting, with a prolonged chemical reaction occupying a period of several days, possibly months. This property cannot be altered or speeded up without reducing the translucency.

There is an initial snap set at approximately 4 minutes from the start of mix, at which time it is possible to remove the matrix and examine for successful placement. However, at this point it is extremely susceptible to water uptake and water loss. It is therefore essential to keep the cement completely covered with a waterproof sealant for as long as possible to allow full chemical maturation before exposure to the oral environment. It should be painted with the sealant as the matrix is removed.

Manufacturers supply special varnishes as sealants, but, because these contain an evaporative vehicle, they remain porous to some degree, thus allowing a water exchange both in and out. If these varnishes are to be used, they should be placed in two layers and dried carefully after each application for a period of approximately 30 seconds (see Figure 1.16).

It has been shown that a more effective sealant is a single-component, very low-viscosity, light-activated, unfilled bonding resin (part of the composite resin system), which has been vacuum-packed and is therefore free of porosities (see Figure 1.17). This should be flowed over the restoration in a generous layer immediately the matrix is removed. The restoration can be trimmed as necessary through this layer. When the contour is satisfactory, further resin bond may be added as required and should then be light-activated. This will produce a complete seal

for at least an hour. Water exchange may occur very slowly over the next 24 hours, at which time the resin sealant can be removed and the restoration polished under air/water spray. Optimum translucency and physical properties can be obtained using this technique (see Figure 1.27).

The cement should not be challenged with dehydration until up to 6 months after placement. If it is necessary to expose an immature restoration during this period, it should be protected again with a further application of the resin bonding agent or the varnish for the time that it is exposed (see Figure 1.30).

Adhesion to enamel and dentine

Chemical union with underlying tooth structure is one of the greatest advantages with the use of the glass-ionomer cements. It means that an erosion lesion does not need to be instrumented, and a carious cavity does not require the traditional mechanical undercut design for retention. There will be no microleakage and, in conjunction with the fluoride release, there will be almost total prevention of recurrent caries.

The smear layer and other surface contaminants left following cavity preparation should be removed with a 10–15-second application of 10% poly(acrylic acid). The area should be washed thoroughly with air/water spray. The tooth should be dried gently, but not dehydrated, and the cement placed immediately.

For the erosion/abrasion lesion where no cavity preparation has been undertaken, it is desirable to remove any plaque or pellicle first by lightly scrubbing with a slurry of pumice and water for 5 seconds. This should be washed off and the area lightly dried. The poly(acrylic acid) is then applied for 10–15 seconds before washing and drying again. The resultant surface will be completely free of contaminants and in a condition to accept chemical union between the restorative cement and the tooth.

Fluoride release

Following successful placement and polishing of the glass-ionomer cement, there will be a high rate of fluoride release for a period of 12–18 weeks thereafter, which can be traced into surrounding and adjacent tooth structure. Although the rate of release will then decline, it has been measured as continuing at a steady level for a further 5 years and probably longer. In the presence of professional or home-applied topical applications of fluoride, and routine use of a fluoride-containing toothpaste, a fluoride balance will develop with the cement, and a continual flow can be predicted.

There is a notable lack of plaque accumulation on glass-ionomer cement restorations, at least in part because of the fluoride release, and tissue tolerance is therefore high (see Figure 1.52).

Pulp compatibility

Pulp tolerance to the glass-ionomer cements has been reported by several authors to be very high, and clinical results substantiate this (Wilson and McLean, 1988). Dentine is a very efficient buffer in itself and the large, complex molecular chains of calcium and aluminium polyacrylate cannot penetrate to any great depth. Recent studies show a mild initial inflammatory response within the pulp tissue, arising from a newly placed glass-ionomer cement, which resolves quite rapidly. Dentine bridging has been shown in animal studies, following closure of a mechanical exposure of an otherwise healthy pulp with a glass-ionomer cement. This suggests that there is no need to place a sub-lining prior to placing a properly mixed glass-ionomer cement.

Physical properties

The physical properties of both the dual cure and the auto cure cements are largely dependent upon the powder/liquid ratio at which they are mixed. This means that materials dispensed in capsules and machine-mixed will generally be superior to those that are hand-mixed.

The physical properties of the dual cure cements, as measured by the shear/punch test, are close to those of a micro-filled composite resin. Fracture resistance is still not sufficient to build a marginal ridge or restore an incisal corner, but they are capable of withstanding some

occlusal load, providing the restoration is well supported by surrounding tooth structure. They are also radiopaque and therefore suitable for the restoration of posterior lesions, which may have to be monitored radiographically.

The auto cure cements are not quite as strong, but their clinical history shows that they are very useful materials except under heavy occlusal load. Most of them are radiolucent, and should therefore be confined to anterior teeth only.

Abrasion resistance is the one property that can be properly tested only in the oral environment. The auto cure cements have a long history showing high resistance to abrasion, but it is not possible to simply transfer this history to the dual cure materials. At the present time there is no evidence of early breakdown, and it is reasonable to assume that they will stand up to oral stress in the same fashion. Only time will tell.

Clinical application

Class I/fissure seal—auto cure cement

Figure 3.2

Bitewing radiograph showing a carious lesion under the distal pit on the occlusal surface of the lower first molar (patient aged 18 years).

Figure 3.3

Occlusal view of the tooth shown in the radiograph. Note the subtle change of colour under the distal pit, suggesting that there may be caries present.

Figure 3.4

Enamel has been removed over the carious lesion, disclosing the extent of the problem. If there is any doubt, open the remaining fissures slightly using a very fine diamond stone, without penetrating through the enamel unless the presence of caries dictates it.

Figure 3.5

On completing the cavity, 10% poly(acrylic acid) is applied for 10–15 seconds, then washed thoroughly with air/water spray.

Figure 3.6

To obtain a completely aesthetic restoration and fissure seal, a Type II.1 restorative aesthetic cement can be used providing there is a degree of radiopacity. The matrix here is a Hawe no. 723 that has been preformed to the occlusal surface.

Figure 3.7

As soon as the cement has set, the excess is cleared from around the matrix, the matrix removed and the area immediately painted with a low-viscosity, light-activated bonding resin. The cement is trimmed as required through the unset resin. Further resin is added as necessary, and light-activated prior to removing the rubber dam or cotton rolls and releasing the restoration to the oral environment.

Figure 3.8

The finished restoration, 1 week after placement.

Class III restoration—auto cure cement

Figure 3.9

An old composite resin restoration on the mesial of the upper right lateral incisor is leaking and discoloured. It is to be replaced.

Figure 3.10

A lingual view of the restoration prior to removal.

Figure 3.11

The composite resin and the recurrent caries have been removed, and the cavity is being conditioned with 10% poly(acrylic acid) for 10–15 seconds.

Figure 3.12

The restoration has been replaced with an auto cure cement and has been covered immediately with a layer of a low-viscosity, light-activated resin to seal it.

Class III restoration—dual cure cement

Figure 3.13

There is a lesion on the root surface at the distal of the upper-right central incisor.

Figure 3.14

The extensive root surface caries lesion has been cleaned, particularly around the periphery. There is still some affected dentine on the pulpal floor, but this will not be removed.

Figure 3.15

The cavity is conditioned with 10% poly(acrylic acid) for 10–15 seconds, then washed and dried lightly.

Figure 3.16

The cavity was restored with a dual cure cement, so it was contoured and polished immediately. Finally a resin glaze was applied and light-activated.

Class V erosion lesion—dual cure cement

Figure 3.17

Extensive erosion lesions on the buccal of the upper-right canine and first bicuspid. They will be restored with a dual cure cement. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

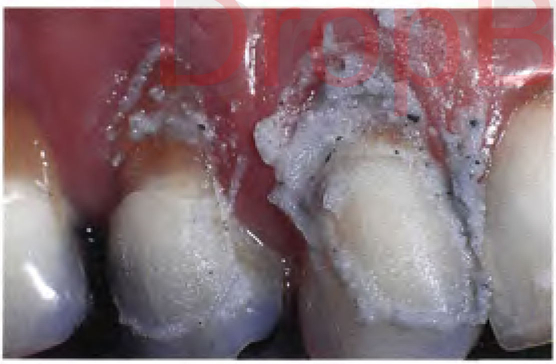


Figure 3.18

The lesions are gently scrubbed with a slurry of pumice and water on a rubber cup, then washed and dried lightly. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 3.19

As the gingival tissue was slightly abraded during the scrub a drop of trichloracetic acid was applied for haemostasis (see Box D, page 54). The cavity was then conditioned with 10% poly(acrylic acid) for 10–15 seconds, washed and dried lightly. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

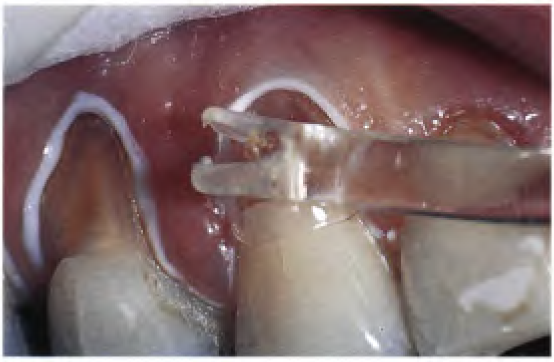


Figure 3.20

Before mixing the cement, select the appropriate translucent matrix (see Box F, page 140), and test it for fit. Adjust it as required. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 3.21

Mix the cement (capsulated for preference), syringe to place and position the matrix. Light-activate for 20 seconds through the matrix. Remove the matrix, and immediately light-activate for a further 20 seconds at least. The restoration can now be contoured and polished with fine diamonds under air/water spray. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 3.22

The restorations immediately after the initial contouring prior to releasing the patient. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Figure 3.23

The restorations 1 year after placement. (Reproduced from Mount GJ, *Quint Int* (1993) **24**: 99–107.)

Class V erosion lesion—auto cure cement

Figure 3.24

Erosion lesions are present at the gingival margins of the upper-right lateral incisor and canine.

Figure 3.25

Prior to cleaning the teeth, soft-tin matrices (Hawe no. 720) are bent to form and tested against the teeth to ensure an accurate fit.

Figure 3.26

The lesions are cleaned with a slurry of pumice and water for 5 seconds only. The pumice is then flushed away and the tooth lightly dried.

Figure 3.27

10% poly(acrylic acid) can now be applied and left for 10–15 seconds before washing and drying lightly. Dehydration should be avoided.

Figure 3.28

The selected shade of cement is now syringed into place and the matrices postioned and left undisturbed while the cement sets. At 4 minutes from the start of mix, the excess cement can be tested for degree of set and then broken away to clear the margins.

Figure 3.29

As each matrix is removed, the cement is immediately covered with a generous layer of an unfilled, light-activated bonding resin. Further trimming can be undertaken through the bond, and more bond applied if necessary.

Figure 3.30

The resin is then light-activated. Note that there is likely to be a small amount of excess resin at the gingival margin, which may act as an overhang. This should be removed with a sharp blade prior to releasing the patient.

Figure 3.31

The finished restorations, 9 years after placement.

BOX D TRICHLORACETIC ACID

The profession has a need for efficient methods of haemostasis. Trichloracetic acid is not new, but has not been popular or routinely used for some years now. However, it is a very safe and reliable method of controlling haemorrhage in areas of local tissue damage, with virtually no side-effects (see Figures 3.19, 3.34 and 4.19). It is highly caustic but self limiting, and therefore does not penetrate far into soft tissue. The resulting eschar separates from the subjacent tissue without producing an inflammatory response, and healing is rapid and uneventful. It will effectively arrest gingival haemorrhage, and will remove granulation tissue to a limited extent only.

- Purchase in crystal form.
- Leave the top off the bottle for a few hours and the crystals will deliquesce, leaving a liquor of concentrated trichloracetic acid.
- Handle with care.
- When required, disperse 2 or 3 drops with a glass pipette into a Dappen's dish.
- Touch the blade of a no. 6 flat plastic instrument or similar into the liquid and convey this to the appropriate place on the soft tissue. Do not apply more than this quantity at any one time. Local anaesthesia is not required.
- The effect will generally be immediate with an eschar formed within 30 seconds. Repeat as necessary.
- Wash thoroughly with water.

Wolfort FG, Dalton WE, Hoopes JE, Chemical peel with trichloracetic acid, *Br J Plastic Surg* (1972) **25**: 333–4.

Heithersay GS, Tissue response in the rat to trichloracetic acid—an agent used in the treatment of invasive cervical resorption, *Aust Dent J* (1988) **33**: 451–61.

Repair of an existing crown—auto cure cement

Figure 3.32

There have been porcelain crowns on the lower-right canine and the second bicuspid as part of a three-unit bridge for approximately 15 years. There are now quite deep erosion lesions at the gingival margins of both abutment teeth. The lesion at the gingival of the second bicuspid extends approximately 2 mm subgingivally, so a minor gingivectomy needs to be carried out.

Figure 3.33

Using electrosurgery, approximately 2 mm of gingival tissue is removed to expose the gingival margin of the erosion lesion.

Figure 3.34

As there was a minor amount of haemorrhage in the gingival tissue following electrosurgery, a very light application of trichloracetic acid (see Box D, page 54) has been applied to control the haemorrhage. This produces instant haemostasis and will repair readily, since the acid is self-limiting.

Figure 3.35

Having gained access to both lesions, they are cleaned with a slurry of pumice and water on a rubber cup and washed thoroughly.

Figure 3.36

The two lesions are lightly dried and then 10% poly(acrylic acid) is applied for 10–15 seconds. The teeth are washed thoroughly again and dried, but not dehydrated.

Figure 3.37

Hawe matrices no. 721 have been preformed, the cement syringed to place and the matrices adapted to position.

Figure 3.38

At approximately 4 minutes from the start of mix, excess cement can be tested for degree of set and removed prior to lifting the matrices. Immediately the matrices have been removed, a generous layer of a very low-viscosity, light-activated resin bonding agent is applied.

Figure 3.39

The finished restorations 1 week after placement, showing the excellent tissue recovery. There is still an excess contour on both restorations, and so they require polishing.

Figure 3.40

The finished restorations, 12 months after placement.

Figure 3.41

The same restorations 4 years later.

Restoration of an erosion lesion on an incisal edge—auto cure cement

Figure 3.42

The incisal edge of the lower-right canine is deeply eroded. However, there is a complete wall of enamel surrounding the entire erosion lesion, so that the glass-ionomer cement will be well supported against lateral and shear stresses.

Figure 3.43

Because of the depth of the lesion, it is virtually impossible to scrub with pumice and water, so it is conditioned with 10% poly(acrylic acid) for 10–15 seconds only. The area is washed thoroughly and dried lightly, but not dehydrated.

Figure 3.44

A Hawe matrix no. 722 is preformed, the cement applied and the matrix repositioned.

Figure 3.45

At approximately 4 minutes from the start of mix, the excess cement is tested and broken away prior to lifting the matrix. The restoration is immediately covered with a generous layer of very low-viscosity, light-activated resin bonding agent. The resin is light-activated prior to releasing to the oral environment.

Figure 3.46

Appearance immediately after removal of the rubber dam. The occlusion should be checked and adjusted as required. If the resin bonding agent has been disturbed during adjustment of the occlusion, a further layer should be applied before allowing the tooth to get wet.

Figure 3.47

Three similar restorations 7 years after placement.

Figure 3.48

A similar restoration of an eroded occlusal surface 8 years after placement. There has been some loss of the cement, but the depths of the erosion are still protected. The incisal edge of the canine has just been restored with a dual cure cement.

Restoration of root surface caries—dual cure cement

Figure 3.49

An old Class V composite resin restoration at the gingival of a lower right canine. The lesion extends around the distal to join up with a failing cermet cement restoration at the lingual/gingival margin.

Figure 3.50

The same lesion from the lingual. A temporary restoration of zinc oxide and eugenol has been placed in the distal part of the lesion.

Figure 3.51

The completed cavity viewed from the labial.

Figure 3.52

The completed cavity, showing the distal and lingual extension. There is some affected dentine left on the pulpal floor, which will not be removed.

Figure 3.53

The cavity has been restored using a dual cure cement, which was placed in three increments from the one mix. A small amount of cement was syringed into the lingual extension and light-activated. The distal section was restored next, and finally the labial section.

Figure 3.54

Each increment was light-activated for 20 seconds, and the final restoration was exposed again for a further 20 seconds from three directions.

Figure 3.55

The finished restoration 6 months after placement, viewed from the labial. Note the satisfactory gingival response.

Figure 3.56

The lingual view of the restoration after 6 months. The patient is applying fluoride daily in a small plastic 'pull down' splint to control root surface caries.

4 Type II.2: Restorative reinforced cements

Description

This category of glass-ionomer cements is designed to provide cements with considerably improved physical properties. As already noted, they generally lack fracture resistance, and this limits their application in the oral cavity. There are several methods being utilized in an attempt to improve this particular property, but none of them so far has made a significant difference. It is likely that an increase will only be achieved at the expense of a degree of aesthetics, but this factor may not be significant because they could still be used in situations where they will be covered or disguised.

The following materials are now marketed in this category, although their physical properties are not significantly improved from the other types. Expectations should not be set too high, and they all need to be covered if aesthetics is important.

Silver cermets

Probably the most widely used material is the so-called 'silver cermet'. This is manufactured by incorporating approximately 40% by weight of micro-fine silver particles, less than 3.5 μm in diameter, in with the powdered glass particles, and then sintering the two together under pressure. Unreacted silver is washed out and up to 5% of titanium dioxide included to modify the colour. The particles so produced are covered with a fine layer of metallic silver and are generally more rounded than in other cements, and this leads to improved handling properties with the potential for high density and low porosity in the finished restoration.

The presence of the silver on the surface of the particles allows for a significant improvement in abrasion resistance, and the surface can, in fact, be burnished. Compressive strength and fracture resistance are also improved, but only to a limited extent. They still cannot be used to rebuild marginal ridges in large restorations. They are widely advocated as a core build-up material, but their limited fracture resistance means that their use should be limited to making-good relatively minor deficiencies rather than providing an entire core. Reinforcement with pins and posts will still not compensate for the low tensile strength, and there should be at least 2–3 mm of sound tooth structure forming the entire gingival cuff of a preparation for a crown (Figures 4.23–4.30).

Adhesion to dentine and enamel appears to be slightly reduced, probably because of the presence of the silver particles. It is a fast-setting cement with early resistance to water uptake, but it remains subject to dehydration for at least 2 weeks after placement. Many restorations show fine surface cracking and crazing later as they mature, although these do not appear to propagate over time.

Because of the presence of the silver, this cement has the same radiopacity as amalgam, but it is closer to tooth structure in colour. It is widely used in situations where aesthetics is not important and the rapid set, early resistance to water uptake and abrasion resistance are of value. Wherever it is placed, it must be well supported by remaining tooth structure and placed in a cavity with a retentive design.

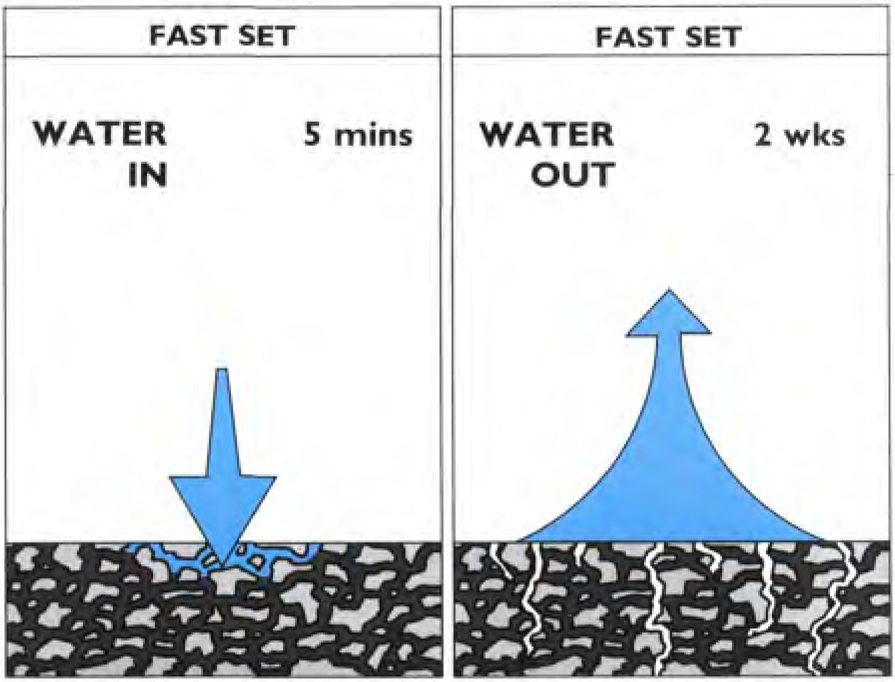


Figure 4.1

Diagram showing the water balance of the Type II.2 glass-ionomer cements. As they are fast-setting, they are resistant to water uptake in about 5 minutes from the start of mix. This means that they can be polished shortly after removing the matrix. However, if they are left exposed to air for any length of time in the first 2 weeks, they are liable to lose water and crack.

Amalgam alloy admix

An alternative method of improving physical properties is to incorporate spherical amalgam alloy particles with a fast-setting glass-ionomer cement powder (J Simmons). The amalgam should be combined in the proportion of 8 parts cement powder to 1 part alloy by volume, and mixed to a suitable consistency with poly(acrylic acid) at a ratio of approximately 3 : 2 by weight. The resultant cement is black and therefore generally needs to be covered by another material to be acceptable. However, the physical properties are slightly improved over the standard cement, particularly in abrasion resistance. It sets rapidly and shows an early resistance to water uptake, so that, when used as a core build-up, further preparation can be carried out immediately it is set (Figures 4.4 and 4.5). Adhesion to underlying tooth structure and fluoride release are both good.

The cement is difficult to mix to the prescribed consistency by hand, but is now available in capsules, and handling properties are good. However, in view of the colour and small improvement in physical properties, it must be regarded as having limited application.

Silver alloy admix

A further alternative is to include a silver-containing alloy in flat broken pieces rather than spheres on the assumption that the flakes will offer a larger surface area for reaction with the poly(alkenoic acid). One company uses an alloy composed of 50% silver, 22% copper and 28% tin, and the powder/liquid ratio is approximately 2 : 1 by weight or 8 : 1 by volume. They claim a higher abrasion resistance because of the development of a Bielby-type smear layer on the surface.

Certainly the physical properties as measured by the shear/punch test are superior to either of the above materials, but remain poorer than those of the dual cure cements (see Figure 1.6).

The colour is a little lighter than the cermet cement, and the fluoride release and adhesion to tooth structure are acceptable.

The future

It is clear that none of the above cements is sufficiently strong to rival amalgam as a true core build-up material, so their applications remain limited. Physical properties, in particular fracture resistance, will need to be improved by at least 50% before the glass-ionomers can be regarded as reinforced and acceptable as restorative materials for posterior Class II lesions under occlusal load.

Research is continuing in a number of areas, including the use of dispersed-phase inclusions and the incorporation of modified poly(alkenoic acid) chains with greater molecular weight. The inclusion of other resins, as has been done with the dual cure cements, has increased the physical properties to a significant level already, but the risk now is that such measures may downgrade the ion-exchange mechanism and the fluoride release, which are the real strengths of the glass-ionomer cements.

Clinical experience over a reasonably long term is the only measure through which a new material can be judged, and the original auto cure cements have proved adequate for all situations that are not subject to undue occlusal load. The next stage will require cements with a fracture resistance similar to amalgam while still retaining the essential systems associated with the present generation.

The following factors apply equally to all three materials mentioned above.

Significant factors

Powder/liquid ratio

In most clinical situations optimum physical properties will be required when utilizing these materials, so the powder/liquid ratio is important. The higher the powder content, the greater the strength but the more difficult they are to mix by hand. The standard ratio ranges between 3 : 1 and 4 : 1, and all are available in capsules as well as for hand-mixing. It is, in fact, difficult to mix properly by hand, the working time is rather short and the final mix is very sticky. Therefore there is a temptation to reduce the powder content when hand-mixing, but this is undesirable because of the reduction in physical properties.

It is strongly recommended that they should be used in a capsulated form to obtain optimum physical properties and results.

Time to mature

These are fast-setting cements and will therefore be resistant to water loss and water uptake as soon as they are resistant to indentation by a sharp instrument. A protective seal will not be required as long as the restoration remains in a wet environment. Contouring and polishing should always be carried out under air/water spray at intermediate high speed using fine polishing diamonds.

Note that the materials remain subject to dehydration for approximately 2 weeks after placement. Therefore if a newly placed restoration is to be left exposed for any length of time or re-exposed within the next 2 weeks, it should be covered and protected with a layer of low-viscosity, single-component, light-activated resin enamel bond to maintain the water balance.

Adhesion to enamel and dentine

Probably because of the presence of the silver or alloy particles, the adhesion through the ion-exchange layer appears to be less with these cements than with the conventional unfilled materials. It is therefore suggested that a small degree of mechanical retention always be included in the cavity design. As usual, the cavity should be conditioned with 10% poly(acrylic acid) for 10–15 seconds to remove the smear layer and enhance the ion-exchange layer to ensure optimum retention.

Fluoride release

Fluoride release seems to be similar to other types of glass-ionomer cement, in spite of the presence of the silver particles. This makes the material particularly suitable for restoring such lesions as root-surface caries and tunnels, where cavity outline is often difficult to determine and remineralization of surrounding tooth structure is important.

Pulp compatibility

As discussed previously (page 26), there is only a short-term inflammatory response in the pulp tissue from a newly placed glass-ionomer cement. In the presence of the ion exchange with dentine and enamel, there can be no micro-leakage leading to bacterial invasion, thus preventing the production of bacterial toxins and other by-products. It is suggested, therefore, that there is no need to place a sub-lining first.

For the same reason, it is only necessary to remove the infected surface dentine from a carious lesion, leaving behind the softened, demineralized, affected dentine, removal of which may lead to an exposure of the pulp. In the presence of the fluoride-releasing cement, the remaining dentine will remineralize and the tooth will probably retain its vitality.

Physical properties

The tensile strength and fracture resistance of the present generation of these materials are only marginally greater than those of the auto cure cements, but the dual cure cements are superior in both properties. However, in abrasion resistance they match up with both amalgam and composite resin, probably because the metal inclusions allow a degree of slip and flow on the surface.

Mainly because of the presence of the silver or silver alloys, radiopacity is of a similar order to that of amalgam.

It seems that their main application is in areas of difficult access where a dual cure cement is contra-indicated and aesthetics is of no concern or in situations where the property of abrasion resistance is of prime importance.

Clinical placement

Minimal Class II cavity

Figure 4.2

A very small lesion on the distal of an upper-right first bicuspid. The marginal ridge was already cracked, so a proximal box has been prepared, but the occlusal groove has not been included.

Figure 4.3

The finished restoration, using a cermet cement, after polishing at the insertion appointment.

Figure 4.4

Placement of an amalgam alloy admix cement to restore an old failed amalgam restoration prior to preparing the tooth for a full crown.

Core build-up for crowns — auto cure cement

Figure 4.5

The crown preparation completed immediately after the amalgam alloy admix had set.

Repair of a crown margin

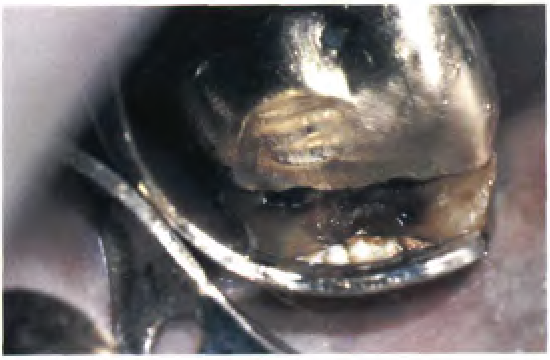


Figure 4.6

Root-surface caries beyond the gingival margin of a gold crown on a lower-right molar.

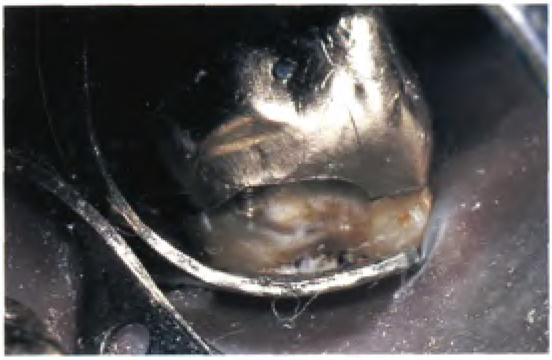


Figure 4.7

The caries has been removed and a limited amount of retention has been placed at the gingival and occlusal margins.

Figure 4.8

The cavity has been conditioned with 10% poly(acrylic acid), and the cement syringed to place and positively adapted with a matrix.

Figure 4.9

Before removal of the rubber dam, the excess cement was trimmed at intermediate high speed under air/water spray. After removal of the dam, the restoration was polished with abrasive rubber points under air/water spray.

Class II restoration of a deciduous molar

Figure 4.10

A carious lesion on the distal of a deciduous lower second molar. The marginal ridge has already been lost.

Figure 4.11

The cavity has been cleaned by removal of demineralized enamel and dentine only, but not extended beyond its original outline. This has allowed maintenance of contact with the adjacent permanent molar and facilitated the development of a relatively normal contact area during placement of the restoration.

Figure 4.12

A short length of mylar strip has been placed as a matrix and firmly wedged in place.

Figure 4.13

The finished restoration, which has been polished prior to removal of the rubber dam.

Repair of an inlay margin

Figure 4.14

A small breakdown has been detected on the margin of an otherwise sound gold inlay.

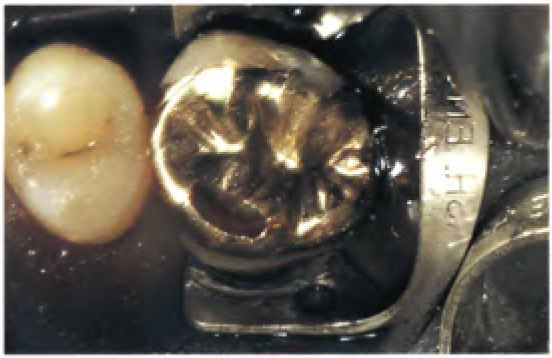


Figure 4.15

The defect has been opened at the expense of both tooth and gold to reveal the extent of the problem. As there is still adequate support for the restoration, a cermet cement is the material of choice for a very conservative repair.

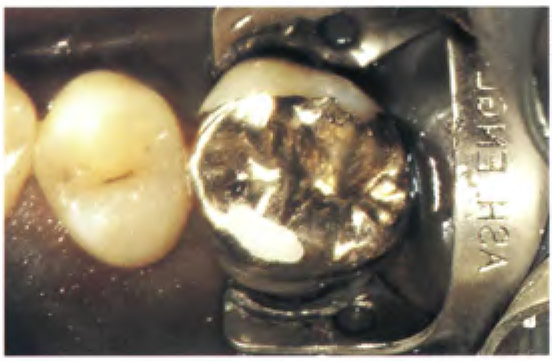


Figure 4.16

The finished restoration, which has been polished prior to removal of the rubber dam.

Class V carious cavity

Figure 4.17

This patient demonstrates considerable gingival recession and now displays a series of small root-surface carious lesions. There are two lesions on the buccal of the lower-right first molar, including the furcation area, and a small one on the second bicuspid, beyond the existing amalgam restoration.

Figure 4.18

Cavities have been prepared, but there is a small amount of damage and thus haemorrhage from the gingival tissue in relation to the two cavities that were partly subgingival.

Figure 4.19

Haemorrhage has been arrested with a limited application of trichloracetic acid (see Box D, page 54), just in the involved areas. As the acid is self-limiting, the tissue will respond and heal readily.

Figure 4.20

Following cavity preparation, the cavities were conditioned with 10% poly(acrylic acid) for 10–15 seconds, and the teeth were washed thoroughly and dried, but not dehydrated. Separate Hawe matrices (no. 719) were preformed to the three lesions and a cermet cement was syringed into place.

Figure 4.21

At 4 minutes from the start of mix, the excess cement was tested first, then broken away and the matrices removed. At this point the restorations were contoured and polished to completion under air/water spray, using very fine diamonds and graded rubber polishing cups and points.

Figure 4.22

The restorations 1 week after placement, showing that the soft tissue has healed completely. The lesion on the second bicuspid, in particular, is already almost submerged into the gingival crevice.

Core build-up for crowns—auto cure cement

Figure 4.23

The upper-right first and second bicuspids were both broken in a motor vehicle accident. Buccal and lingual cusps were lost from the first bicuspid and buccal cusp only from the second, and both required root-canal treatment.

Figure 4.24

The root canals in both teeth have been obturated and the remains of existing restorations removed.

Figure 4.25

Stainless steel posts have been cemented into both teeth. The posts in the first bicuspid protrude beyond remaining tooth structure because it was anticipated that the core would be built up to that level. The posts in the second bicuspid were cut off to just below the proposed core height because the entire lingual cusp was still present and would provide support. Remaining tooth structure was conditioned with 10% poly(acrylic acid), then washed thoroughly and dried, but not dehydrated.

Figure 4.26

A standard metal matrix has been placed on the first bicuspid and a cermet cement syringed into place incrementally. Each increment was tamped into place with a small plastic sponge (see Figure 7.25) to ensure full adaptation to underlying tooth structure and around the two posts.

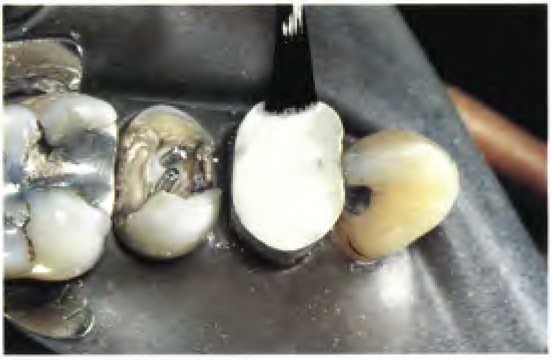


Figure 4.27

The build-up on the first bicuspid is complete and the matrix removed. However, since this was to remain isolated and dry for a period while the second bicuspid was restored in the same way, the freshly placed cement was covered with a generous coating of a very low-viscosity, light-activated bonding resin to prevent water loss in the short term.

Figure 4.28

The cermet cement core has now been built up on both teeth.

Figure 4.29

A buccal view of the finished crown preparations at the time of gingival retraction. Note that there is at least 2–3 mm of natural tooth structure between the cement core and the gingival margin on both teeth, except in relation to the distal proximal boxes.

Figure 4.30

A palatal view of the prepared teeth. On the first bicuspid there is at least 3 mm of normal tooth structure between the cement and the gingival margin. On the second bicuspid there is the full height of the palatal cusp. This ensures maximum resistance against lateral stresses and minimal load on the cement core.

Core build-up for crowns—dual cure cement

Figure 4.31

An upper-right first bicuspid with the buccal cusp isolated and weakened by the presence of a moderate-size amalgam restoration. The patient has reported pain on pressure.

Figure 4.32

The amalgam has been removed, revealing the crack at the base of the buccal cusp.

Figure 4.33

To allow immediate preparation of the tooth for a full crown, the cavity was restored using a dual cure cement lightly supported with a mylar strip as a matrix. To ensure complete light activation the cement was built incrementally and light-activated from several directions.

Figure 4.34

The preparation for the full crown was completed during the same appointment. Strength for the retention of the crown is provided by the remaining 2–3 mm of sound tooth structure in the gingival one-third of the tooth, as well as the remaining lingual cusp.

Repair of a broken cusp

Figure 4.35

There has been a limited failure of enamel from the mesio-lingual cusp of an upper molar. As the occlusal load is still borne by the amalgam as well as by the disto-lingual cusp, a minimal cavity was prepared. The amalgam was dressed back and a small amount of retention was included.

Figure 4.36

The completed restoration.

Figure 4.37

A similar repair using a cermet cement 8 years after placement.

5 Type III: Lining cements

Description

As discussed earlier, this group can be divided into *lining cements* and *base cements*, and this latter category could be more accurately described as a *dentine substitute*. The only difference between the two is the powder/liquid ratio, but the physical properties, and thus the expectations, will be much greater for the latter.

Definition

Lining

A lining can be defined as a thin layer of a neutral material placed prior to final restoration to make good a deficiency in cavity design or provide thermal protection to the pulp (Figures 5.7–5.9). A lining is not expected to have any therapeutic effect on pulp tissue, unless there is an exposure.

Base

A base can be regarded as a *dentine substitute* which is placed to make up for major areas of dentine loss prior to the placement of an enamel substitute over the top. It can also be used as a method of bonding composite resin to dentine (Figures 5.18–5.25).

Auto cure or dual cure cements can be used for either application. The dual cure cements generally have better physical properties, and are therefore of value particularly as dentine substitutes. Their main limitation is that they may be contra-indicated where there is a lack of access for the proper application of the activator light.

Care must also be exercised in the selection of the proprietory product because there have been a number of materials put on the market classified as glass-ionomer cements that do not properly fit into this category. These non-glass-ionomer cements consist of a light-activated resin with an ionomer-glass filler. They contain little or no poly(alkenoic acid), and are therefore not capable of the usual acid/base reaction leading to the ion exchange with underlying tooth structure. Nor do they release fluoride over the long term.

As pointed out previously (pages 6–7), the easiest way of identifying a true dual cure glass-ionomer cement is to place a trial mix under a light-proof cover and note the time required for a chemical set to occur. A true glass-ionomer cement will achieve a reasonable degree of set within 10 minutes. Most of the non-glass-ionomer cements will not set at all, but some will achieve a soft rubbery phase in about 15 minutes and will not progress beyond this stage without light activation. While non-glass-ionomer materials may provide adequate thermal protection, they should not be expected to provide any further benefit, and, because of their potential for high water uptake, they should certainly not be exposed to the oral environment.

The concept of a base goes back to GV Black, who suggested that there was a need to 'base out' a deep cavity so that the cavity design could be refined to the 'ideal' geometric shape before the placement of amalgam. Linings were developed later on the understanding that there would be some therapeutic effect upon the pulp tissue to compensate for the trauma initiated by active caries followed by the preparation of the cavity. These theories sometimes even dictated removal of sound dentine to make room for the lining. Many complex techniques have been described, and apparent benefits to the health of the pulp have been demonstrated.

However, recent work has shown clearly that the pulp has far greater powers of recovery than

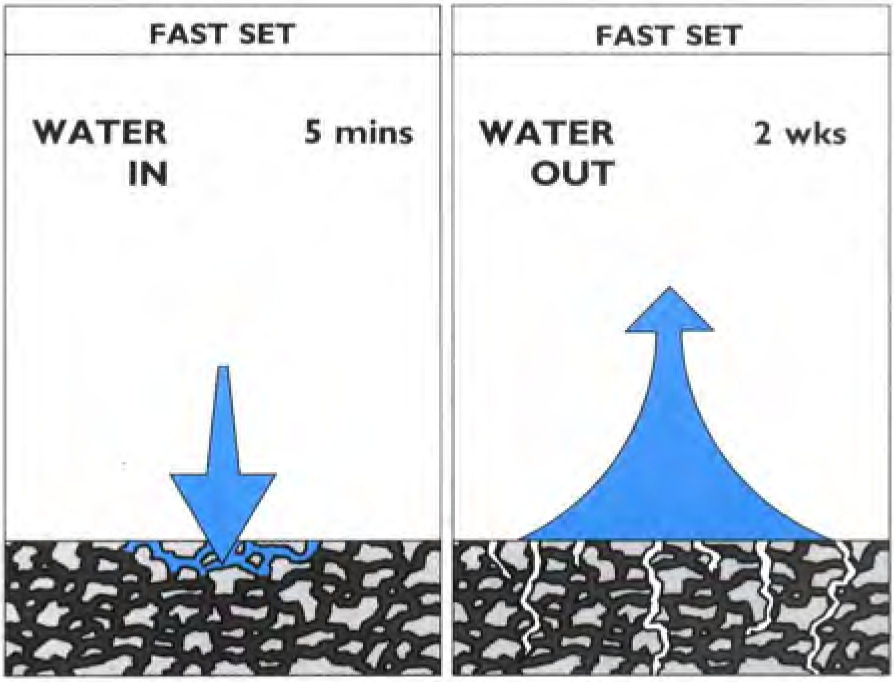


Figure 5.1

Diagram showing the water balance of the auto cure Type III glass-ionomer cements. As they are fast setting, they are resistant to water uptake in about 5 minutes from the start of mix. This means they can be etched shortly after removing the matrix. However, if they are left exposed to air for any length of time, they are liable to lose water and crack.

were ever suspected, and that a therapeutic effect from a lining material through sound dentine does not exist. The presence of bacteria—in particular future invasions of bacteria under a newly placed restoration—is far more deleterious to the pulp, and can lead, through continuing inflammation, to post-insertion sensitivity and to pulp death. In fact, if a healthy, uninfected pulp is mechanically exposed, it is only necessary to seal it from bacterial invasion for it to heal.

The purpose of placing a traditional lining, then, is threefold:

- When restoring a tooth by an indirect technique, it may be desirable to modify a cavity to allow for a simplified line of withdrawal and insertion.
- If the cavity is deep and penetrates more than half way to the pulp, and a metallic restoration is to be placed, a thin layer (0.5 mm) of a lining material may offer a degree of thermal protection to an inflammed pulp and keep the patient comfortable during the period of healing.
- A lining can seal the restoration margin against bacterial invasion. There will inevitably be bacteria left behind at the time of restoration, but, providing the cavity is sealed, these will adapt to a spore form and remain inactive. The problem arises when there can be ingress of nutrients and new bacteria from the oral environment. Bacterial activity, resulting in production of toxins, will lead to continuation of any existing pulpal inflammation, and, possibly, to pulp death.

The material that will provide the most effective long-term seal to dentine is glass-ionomer cement.

It is necessary, then, to consider the main restorative materials and determine the best method of obtaining optimum results using glass-ionomer cement as the primary dentine sealant to prevent microleakage.

Indirect restorations

Placement of a lining in relation to such restorations is generally a convenience to reduce the problems of impression-taking, construction of models and the development of a line of withdrawal and insertion of the finished restoration. The need for sealing dentine against bacterial invasion is minimal, but thermal protection may be indicated. The ultimate integrity of the marginal seal will depend on accuracy of laboratory techniques followed by the use of a cement with thermal properties close to those of tooth structure and with low solubility. Glass-ionomer cements offer these properties.

Amalgam

In the past it was considered essential to place a lining under an amalgam restoration for both thermal and therapeutic properties. In fact, it was taught that the cavity should be extended sufficiently to make room for the extra material. It has now been shown that the therapeutic properties are neither available nor necessary, so the need for a lining is confined to those cavities that are already relatively deep and in close proximity to the pulp. Removal of additional tooth structure is strictly contra-indicated. The lining should be placed in thin section, and only where necessary, thus leaving room for the amalgam to be placed in bulk and to develop optimum physical properties.

Amalgam shows a unique ability to seal its own margins through corrosion, and the initial placement of copal varnish to control this has been well tested over many years. Even the modern non-gamma 2 alloys will allow sufficient corrosion over time to prevent bacterial invasion. This means that adhesion between the dentine and a lining cement is probably unnecessary. However, it has been shown that fluoride released from a glass-ionomer cement lining is, in fact, available externally through the margin, and will offer the usual protection against bacterial activity and demineralization.

Therefore, where amalgam is the material of choice, and the cavity is of minimal dimension, no lining need be placed and the corrosion factor can be relied upon to provide a marginal seal. For a cavity that has progressed further than half way to the pulp a small quantity of glass-ionomer cement lining material should be placed in the vicinity of the pulp. There is no need for the placement of an additional 'therapeutic' lining. For convenience and ease of placement a low powder/liquid ratio mix is adequate, because the cement will not be subjected to undue load and optimum physical properties will therefore not be required. The cement used can be either a dual cure or an auto cure, and at a ratio of 1.5 : 1 it will flow readily, be easily placed and may be set on command.

An alternative situation can arise when a Class II proximal lesion proves to be extremely deep and the placement and proper condensation of amalgam poses problems. Under these circumstances, it is possible to use a lamination technique, with the glass-ionomer cement restoring the subgingival section of the cavity and the amalgam overlay protecting the cement from undue occlusal load. As the cement will be exposed to the oral environment and subject to some load, it is essential to use a high powder/liquid ratio to develop the best possible physical properties (Figures 5.10–5.17).

Providing there is sufficient access for the placement of the activator light, a dual cure cement can be placed, although the Type II.2 auto cure cements have proved adequate. Having completed the cavity design, place a short length of either a metal or mylar matrix strip and support lightly with a wedge. Condition the cavity and place a large quantity of cement sufficient to extend to within 2–3 mm of the contact area. Tamp the cement into place to ensure proper adaptation of the cement to the cavity floor and walls. As soon as the cement is set, cut it back and contour to a final amalgam cavity design, including retentive grooves and ditches to allow for a mechanical interlock between the cement, the tooth and the amalgam. Make sure there is sufficient room for the amalgam, because this will be the ultimate restoration, which is required to accept the full occlusal load and, in many such situations, protect both the cement and the remaining tooth structure.

If a small quantity of poly(acrylic acid) is lightly smeared onto the cement surface at this point, it is possible to develop some degree of chemical union between the cement and the amalgam. Paint copal varnish over the remaining cavity walls and pack the amalgam.

The resultant laminated restoration has all the advantages of the strength of amalgam, combined with the marginal seal, tissue tolerance and fluoride release of glass-ionomer cement. It also overcomes the problems of proper condensation, contouring and polishing of amalgam in inaccess-dible interproximal regions without leaving an overhang.

The same concept can be applied for the design and placement of indirect restorations, although in many instances, if a tooth is so badly broken down, it is likely that an extracoronal restoration will be preferred. However, there may be occasions where replacement of dentine in such a manner may simplify the design of a gold or porcelain inlay, leading to the preservation of a significant amount of normal tooth structure.

Composite resin

Long-term adhesion of composite resin to enamel is no problem, and can be achieved through the acid-etch technique pioneered by Buonocore. However, long-term adhesion between composite resin and dentine continues to pose difficulties. The main obstacles appear to be the setting shrinkage of the material and the hydrolytic breakdown of the resin component, and these are proving difficult to overcome.

The setting shrinkage of composite resin complicates the situation regardless of the curing mechanism used. Depending on how heavily the resin is filled, shrinkage can vary from 1 to 5% of bulk. When the curing mechanism is chemical, the direction of shrinkage will be towards that area of the restoration that sets first. This will generally be towards the floor of the cavity, where the temperature of the tooth may well be the initiating factor. Certainly the shrinkage will be more inwards and towards the tooth than the reverse. There will be some stress exerted on the bond to dentine, but, since the chemical reaction is relatively slow, the stress will be generated slowly and may not be excessive.

However, if the composite resin is light-activated, the setting reaction will commence immediately adjacent to the light source, and, depending on the total volume shrinkage expected of a particular composite resin, there will be considerable stress applied to any adhesive mechanism at the tooth/restoration interface. The total shrinkage can be minimized by building the restoration incrementally and light-activating in such a direction that the resin will shrink towards, rather than away from, the cavity floor and walls. This technique is satisfactory in theory, but not always available in practice.

The problem, then, is to develop a union between dentine and resin that will withstand the stresses of the setting reaction and maintain a sound margin at the interface. It is currently suggested that dentine can be safely etched with various concentrated acids while the buffering capacity of the dentine is relied upon to protect the pulp. This will then lead to a mechanical interlock into the dentine tubules such as that developed with acid-etched enamel. However, the anatomy of the dentine tubules is not necessarily regular and uncomplicated, and etch patterns may well be variable. Also this still does not overcome the hydrolysis problem.

Many techniques have been explored to develop a chemical union rather than a mechanical one, and these are becoming increasingly complex and difficult to apply correctly in clinical practice. Evidence suggests that none of these so far remain sound, over time, in the presence of hydrolysis.

The use of glass-ionomer cement as a bonding mechanism between dentine and composite resin has been extensively explored over recent years, and offers a high level of reliability along with tissue compatability and fluoride release. This requires that the cement is used as a base and not as a lining. The cement will develop the usual ion exchange with the dentine, and a mechanical or chemical union can be developed between the cement and the resin, thus leading to the production of a 'monolithic' reconstruction of the tooth. Providing the cement is used as a base or dentine substitute rather than as a lining, the composite resin can be laminated over the cement as a final restoration.

As glass-ionomer cement is a water-based material, it relies on the continuing presence of water for stability, and the question of hydrolytic breakdown does not arise. However, the setting shrinkage of the composite resin must be understood and taken into account, and this means that only the strongest glass-ionomer cements can be relied upon to produce and maintain a sound union with dentine. There is no doubt that the

Figure 5.2

A cross-section through a molar tooth showing a simulated design for a 'sandwich' restoration using a cement with a powder/liquid ratio of 3 : 1. In one proximal box there is no enamel at the gingival margin. The cement has therefore been built up just short of the contact area, and will be left exposed in the oral cavity. At the other end there is sufficient enamel to bevel and etch, so that the cement remains short of the margin and the union is composite resin to enamel. Note the thickness of cement over the entire cavity floor.

bond between sound acid-etched enamel and composite resin is the strongest available, and should be utilized where ever possible. But, if there is no enamel available, or that which remains is weak and friable, a strong glass-ionomer cement will be adequate as long as it is properly placed and protected from undue occlusal load.

The technique for clinical placement of the so-called 'sandwich technique' restoration is relatively simple and straightforward (Figures 5.18–5.25). The cavity should be prepared as conservatively as possible. It is unnecessary and undesirable to remove any more tooth than is essential to achieve access to the active carious lesion and then develop clean sound walls around the entire circumference. It is necessary to remove all infected dentine, but remaining demineralized affected dentine can remain as long as the periphery is sealed against oral flora and access to nutrients. Where possible, develop sound enamel walls and polish these lightly to remove free enamel rods. Where there is no enamel at the periphery, develop clean dentine for union with the cement.

Place a matrix as required, and support it lightly with appropriate wedges. Condition the cavity as previously described (page 18) and fill the entire cavity with a Type II.1, II.2 or III cement using a high powder/liquid ratio. If using a dual cure cement, always place the cement incrementally and light-activate each increment for a minimum of 20 seconds.

The cavity can now be re-developed in the cement to allow sufficient room for a laminate of composite resin without regard to the original cavity outline. Expose and polish all sound enamel walls to allow for the use of the acid-etch technique union. In a proximal box cut the cement back to just below the contact area, because it is better to utilize the superior strength of composite resin for the new contact. Mechanical interlocks are unnecessary, because auto cure cements can be acid-etched to develop a mechanical union with the composite resin and dual cure cements contain sufficient free radicals in the resin component to obtain a chemical union.

The prepared cavity can now be etched for 15 seconds with 37% orthophosphoric acid. If using an auto cure cement, the entire cavity, enamel and cement should be etched (Figures 5.4–5.6). When using a dual cure, it is not necessary to etch the cement, but it will do no harm if the acid gets onto it. Having washed the cavity well and dried it lightly, paint the cement and the cavity walls with a light coat of a very low-viscosity unfilled enamel resin bond and blow off any excess before light-activating it.

Replace the matrix, and this time wedge it firmly to open the interproximal space for the development of a firm contact in composite resin. The composite resin laminate can now be placed. When using a light-activated resin, build it incrementally and cure it in such a way as to make

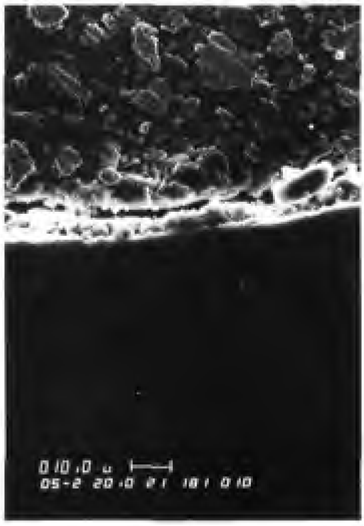


Figure 5.3

SEM showing the ion-exchange layer formed between the dentine and cement. Note that failure has occurred in the cement owing to dehydration while preparing the specimen for viewing, but the ion-exchange layer stays firmly adherent to the dentine. *Original magnification × 500.*

it shrink towards the tooth structure or onto the cement.

The advantages of this technique include maximum exposure of glass-ionomer cement to the oral environment for the release of fluoride and a reduction in the total amount of composite resin commensurate with required strength in the ultimate restoration. Also, it is desirable to replace the interproximal tooth structure with the cement because of its resistance to plaque build-up and high tissue tolerance. While the occlusal load will be dissapated to some degree by the composite resin, it is important that only the strongest possible glass-ionomer cement be used so that it can offer maximum support for the composite resin and will not be subject to dissolution and erosion interproximally.

Significant factors

Powder/liquid ratio

The physical properties of these cements depend upon the powder/liquid ratio, so that if high strengths are required in the ultimate lining, such as in the 'sandwich' technique, a high powder/liquid ratio, of at least 3 : 1, must be used. The higher the powder content, the shorter will be both the mixing time and the working time. While most of the lining cements are marketed for hand-mixing, the capsulated varieties, which can be machine-mixed, will provide more reliable results with better physical properties because they will have the correct powder content.

Cements with a low powder/liquid ratio, in the range of 1.5 : 1, are useful as all-purpose cavity linings, but they are not strong enough to be used under composite resin unless there is a complete margin of sound enamel around the circumference of the cavity. In thin section their tensile strength will not be high, but the rapid-setting reaction means early achievement of a compressive strength high enough to withstand the heavy packing pressure used in the placement of amalgam. At this consistency, they are also useful for correcting minor deficiencies when carrying out crown preparation. For correcting major defects, the heavier 3 : 1 ratio should be used.

Time to mature

All the auto cure cements in the Type III category are designed to be fast-setting and therefore resistant to water uptake within 5 minutes from the start of mix. They should undergo a snap set at that point and be ready for trimming as required and the placement of the final restoration. If several restorations are being placed at the same

time, care must be taken to ensure the cement does not dry out, particularly when working under a rubber dam. For the same reason, when they are used as a dentine substitute, all trimming should be undertaken under air/water spray.

Dual cure cements can be used for either application, and the problems of water loss can be avoided. However, proper activation of the cement is necessary, and access for the placement of the light may be a limiting factor. If an extensive build-up is required in a difficult situation, such as a distal proximal box in a molar tooth, then an auto cure cement may be required. On the other hand, incremental placement of a dual cure cement may suffice.

Adhesion to enamel, dentine and composite resin

Chemical adhesion is available between the cement and underlying tooth structure, provided that the smear layer and other debris have been removed first by conditioning with 10% poly(acrylic acid) for 10–15 seconds. However, if the cement is being used simply as a conventional lining under an amalgam, for example, then this step is unnecessary and can be omitted (Figures 5.7–5.9).

If the cement is to be used as a base or dentine substitute under composite resin in the 'sandwich' technique, there are two interfaces to be considered (Figure 5.2):

- the union between the cement and the dentine
- the union between the cement and the composite resin.

With both auto cure and dual cure cements the union with tooth structure will arise through the ion exchange between the two, and will be enhanced by prior conditioning with poly(acrylic acid).

The union between the composite resin and the cement is either mechanical or chemical. With the auto cure cements it is necessary to etch the cement with 37% orthophosphoric acid for 15 seconds to develop a roughened surface, rather like etched enamel, to ensure a mechanical union between the two. Etching for a longer period of time will only remove further cement and not improve the bond. Application of a thin layer of enamel resin bond will ensure a good union.

The dual cure cements, however, still retain a number of unreacted resin bonds, and these are generally sufficient to develop a chemical union between the two materials. Etching is unnecessary, but will do no harm if some acid does get onto the surface. Application of a resin enamel bond will ensure good adaptation between the two materials.

In theory, the technique should work well and provide the optimum 'monolithic' restoration. However, there are some limitations, and the following points should be taken into account.

The tensile strength of the cement is the weakest link in the chain. Therefore the strongest cement available should always be used, particularly if the restoration is to be subjected to heavy occlusal load. The Type III lining cements have been developed with this technique in mind, and the Type II.2 cements are also satisfactory. The dual cure Type II.1 restorative aesthetic cements have superior physical properties and better aesthetics, so they are also valuable in the laminate technique. In a situation where aesthetics is of primary concern, such as a Class IV lesion, this is the material of choice (Figures 5.26–5.31).

The dentine should be conditioned with a 10–15-second application of 10% poly(acrylic acid) to remove the smear layer and any other contaminants that may be present. This will also pre-activate the calcium ions in the dentine in preparation for the ion exchange with the cement (Figure 5.3).

The cement must cover all dentine tubules, should never be less than 1 mm thick, and the highest powder/liquid ratio available should be utilized. The cement can then be left exposed to the oral environment at the gingival margin of the restoration and full advantage taken of the adhesion to dentine as well as fluoride release. A cement with a low powder/liquid ratio should not be exposed to the oral environment at the margins of a restoration, because its physical properties are not good enough.

Fluoride release

Fluoride release is relatively insignificant if the cement is to be entirely covered by another restorative material, such as amalgam or composite resin. However, there are many circumstances in the sandwich technique where the cement will

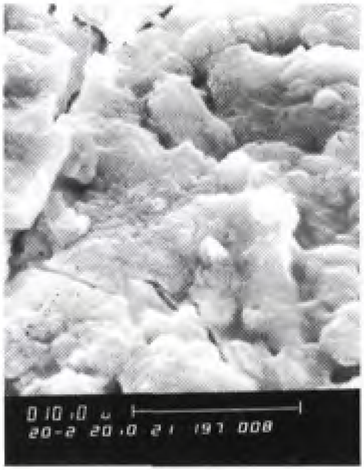


Figure 5.4

SEM of the surface of a glass-ionomer cement that has been cut back after setting but has not yet been etched. Note the matrix investing the glass particles and holding them together. *Original magnification* × *2000.*

Figure 5.5

SEM of a glass-ionomer cement after etching for 15 seconds with 37% orthophosphoric acid, showing removal of the matrix and development of deep clefts between the particles, into which a low-viscosity resin bonding agent will penetrate. *Original magnification* × *2000.*

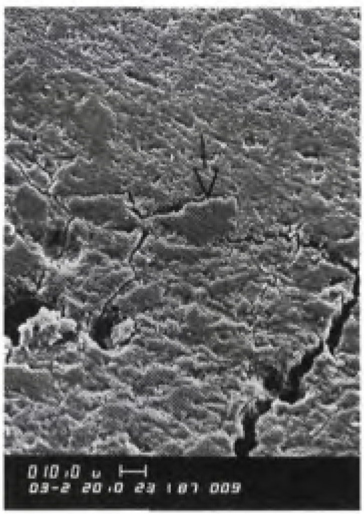


Figure 5.6

SEM of the union between glass-ionomer cement and composite resin. Note the intimate meeting at the interface. The cement is Ketac-fil and the resin is Visio-fil, with Visio-Bond used as the low-viscosity unfilled resin bonding agent. The crack in the cement is an artefact caused by dehydration of the specimen during preparation for viewing under the SEM. *Original magnification* × *300.*

be exposed to the oral environment at the gingival margin, underneath the other material. Fluoride release will then be useful for caries control in both the restored tooth and adjacent ones (Figure 5.2).

Physical properties

The higher the powder content, the better the physical properties of the cement, and capsulation will remove all the variables from dispensing. Low powder/liquid ratios are acceptable only when the cement is to be entirely submerged under another restorative material and is not intended to be etched.

All of the Type III lining cements are radiopaque, as are most of the Type II cements. It is essential that radiopacity be available in situations where monitoring with radiographs is required, and this will apply to all posterior restorations and occasionally to anteriors.

Clinical application

Lining under an amalgam

Figure 5.7

An upper-right first molar with a large cavity present, including the loss of the entire lingual cusps. The radiograph confirms that the pulp has receded and is still vital, and a glass-ionomer lining cement is to be placed. It can be either chemically activated or light-activated.

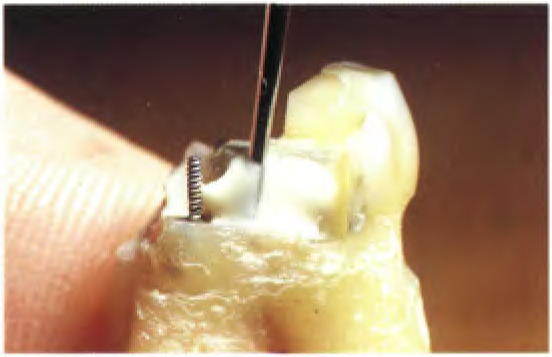


Figure 5.8

As the lining is to be entirely covered by amalgam, there is no need to condition the cavity. The cement will be placed at a powder/liquid ratio of 1.5 : 1, using a small calcium hydroxide placement instrument to paint the cement lightly over the dentine surface (simulated).

Figure 5.9

The cement placed on the floor of the cavity (Figure 5.7) showing the full extent of the area to be covered. Note that the retention for an amalgam restoration is to be achieved with ditches and grooves.

Class II cermet cement/amalgam lamination restoration

Figure 5.10

A large cermet cement restoration of a distal Class II lesion in the lower-right first molar. There is an open contact with the adjacent tooth because of the difficulty of contouring a restoration of this size in using this material.

Figure 5.11

Bitewing radiograph shows that the cermet cement has been poorly placed at the gingival, that there is a rough proximal contour and that caries is still present. Note recurrent caries in the opposing first and second molars and a distal cavity in the lower-right second bicuspid.

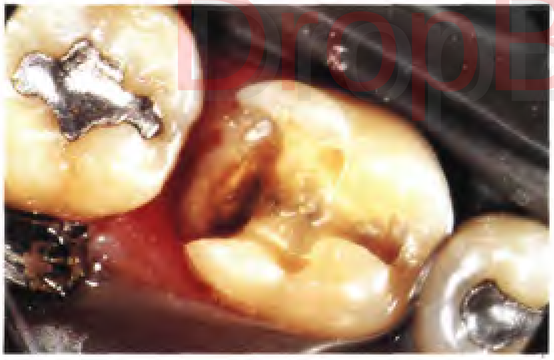


Figure 5.12

Cavity design has been completed in the lower first molar. The rubber dam has been lifted mesially to show the condition of the gingival tissue in relation to the gingival margin of the cavity. The tissue tolerance of the original cermet cement was such that the gingival tissue remained moderately healthy.

Figure 5.13

A standard metal matrix has been placed without a matrix retainer and gently wedged at the gingival to give a degree of support without distortion (see Box G, page 141). The cavity was conditioned with 10% poly(acrylic acid) for 10–15 seconds and then overfilled with a cermet cement, which was tamped into place with a small plastic sponge (see Figure 7.25). It was left to set for 6 minutes.

Figure 5.14

The cement was contoured under air/water spray at intermediate high speed to just below the contact area with the adjacent second molar. Normal mechanical interlocks cut in the remaining tooth structure support the amalgam, and a groove cut in the cement ensures an interlock. A thin layer of cement has been left on the pulpal floor as a normal lining. A very small quantity of 45% poly(acrylic acid) was applied to the cement on a cotton pledget and left for 1 minute. Excess was wiped off, but not washed off.

Figure 5.15

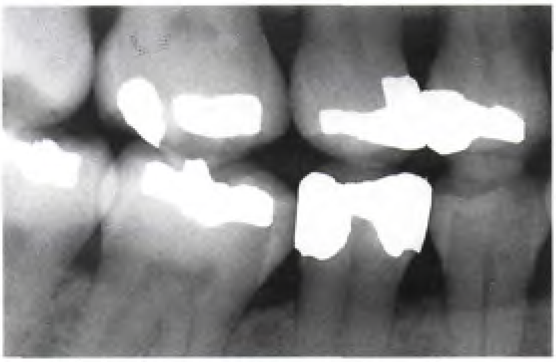
A normal amalgam matrix was applied and the amalgam condensed as usual. Note the protective cavity design. The tunnel cavity in the second bicuspid was also restored with a cermet cement. The occlusal of this restoration was subsequently laminated with composite resin.

Figure 5.16

Bitewing radiograph showing the finished restoration in the first molar as well as the tunnel restoration in the second bicuspid. The upper-right first and second molars have also been restored with amalgam over a cermet cement in a similar fashion.

Figure 5.17

A simulated restoration on an extracted tooth sectioned mesio-distally to show the cement occupying the gingival half of the cavity and spread over the pulpal floor as well as a lining. Note that there has been a small amount of mechanical retention provided along the gingival floor to compensate for the relative weakness of the ionic bond between dentine and the cement (page 62).



Class II dual cure glass-ionomer cement/composite resin lamination restoration

Figure 5.18

A bitewing radiograph of the right-hand side shows the MOD restoration in the second bicuspid in need of replacement and a small proximal lesion in the mesial of the first molar. Both restorations will be carried out as dual cure cement/composite resin laminates.

Figure 5.19

Occlusal view showing the faulty amalgam restorations.

Figure 5.20

The cavity has been prepared in the second bicuspid. Only the minimum of remaining tooth structure has been removed, and there is no retentive design incorporated.

Figure 5.21

A mylar strip was lightly wedged for support both mesially and distally to form a matrix, and the cavity was filled to excess with the dual cure cement. It was light-activated from several aspects for 20 seconds on each occasion to ensure the cement was adequately set.

Figure 5.22

The cement was cut back at intermediate high speed under air/water spray to expose all enamel margins and allow for the rebuild of the contact areas in composite resin. The proximal boxes were left substantially restored with the cement.

Figure 5.23

The enamel margins were etched with orthophosphoric acid for 15 seconds only, and then washed thoroughly and dried.

Figure 5.24

A light coating of a low-viscosity enamel bonding resin was applied and light-activated, and the remaining cavity was restored incrementally with composite resin. This illustration shows the finished bicuspid and, in part, the finished molar.

Figure 5.25

A bitewing radiograph showing the completed restorations. Note the radiopacity of both the glass-ionomer cement and the composite resin.

Repair of an incisal edge—dual cure

Figure 5.26

The incisal corner of an upper central incisor has fractured following a fall. The corner was weakened by the presence of a small Class III composite resin on the mesial.

Figure 5.27

The finished cavity was conditioned with 10% poly(acrylic acid) for 10–15 seconds, then washed well and lightly dried.

Figure 5.28

Using a mylar strip as a matrix, the cavity was overfilled with a dual cure cement and light-activated. Note that 20 seconds of light activation from the labial left the lingual gingival region of the cement still unset. The light was applied for a further 20 seconds from the lingual to ensure complete set.

Figure 5.29

The cement was cut back to expose all the labial enamel margin, which was then bevelled. The lingual remained restored in cement to within 2–3 mm of the incisal edge.

Figure 5.30

The enamel only was etched with orthophosphoric acid for 15 seconds, washed thoroughly and dried lightly. There was no need to etch the cement, because it will chemically unite with the composite resin. A light application of a low-viscosity enamel bonding resin was applied and light-activated before building the final restoration.

Figure 5.31

The completed restoration in composite resin, which was built incrementally and light-activated from both labial and lingual.

Repair of a traumatized incisal edge—auto cure

Figure 5.32

Following a motor vehicle accident, this patient presented for emergency treatment with a Class II fracture of the distal incisal corner of the upper-left central incisor. Dentine was exposed, but the pulp was still covered and vital.

Figure 5.33

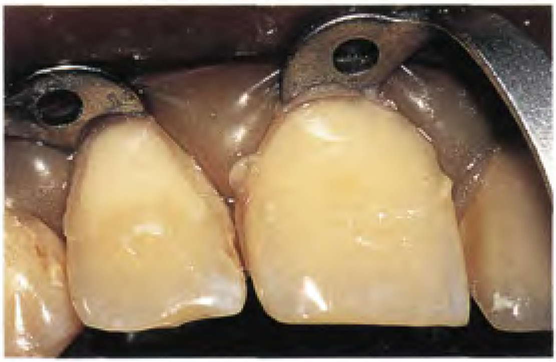
The surface was conditioned for 10–15 seconds with 10% poly(acrylic acid), flushed and lightly dried. A Type II.1 restorative aesthetic cement was syringed over the dentine, without building up the incisal corner. No matrix was used. Prior to complete set of the cement, it was covered with a very low-viscosity, light-activated bonding resin to prevent hydration or dehydration. The bond was activated, and the patient was immediately comfortable and safe.

Figure 5.34

Four weeks later, pulp tests suggested that the tooth had settled down and was unlikely to lose vitality, and so it was restored with composite resin. The cement was very lightly cut back to a fresh surface, the enamel was bevelled and both cement and enamel were etched with 37% orthophosphoric acid for 10–15 seconds. Composite resin was used to build up the corner.

Figure 5.35

The final restoration, photographed at the next 6-month recall visit. Pulp testing showed that the tooth was still vital.



Comparison of glass-ionomer cement with composite resin laminate

Figure 5.36

Two extensive Class V lesions on the upper right central and lateral incisors have been restored with an auto cure glass-ionomer cement. The shade match on the lateral incisor seemed to be less than ideal, so it was decided to laminate it with composite resin.

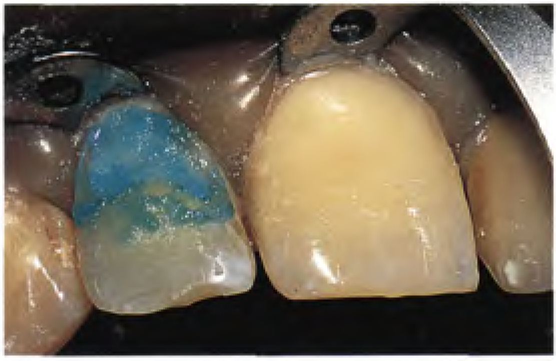


Figure 5.37

The cement was cut back to a depth of approximately 2 mm. The cement and the enamel were etched for 15 seconds, washed thoroughly and dried lightly.

Figure 5.38

The surface was covered with a light application of a low-viscosity unfilled resin enamel bond, and composite resin was built incrementally to complete the restoration.

Figure 5.39

The two restorations 2 years after placement. It is still difficult to determine which is the glass-ionomer cement and which is the composite resin.

6 Modified cavity designs suitable for restoration with glass-ionomer cements

In the past dentists have been faced with a quandary in the restoration of a carious lesion. The tooth to be restored is already damaged and weakened by the presence of caries, and it has been necessary to inflict further damage on the tooth simply to make room for the effective placement of the material being used for the repair. For example, what began as a very small lesion may become a relatively large restoration so that adequate condensation pressure can be applied to amalgam. Composite resin does not flow very readily, and acess and convenience form need to be extended to allow correct placement. Restorations constructed using an indirect technique require the removal of considerable amounts of sound tooth structure to allow for development of a correct line of insertion.

The situation is made worse by the fact that no restorative material can be regarded as permanent, and it is understood that there will, in time, be further breakdown of either tooth or restoration. The cavity will inevitably become larger and the remaining tooth structure will be weakened. Thus the cycle is likely to move faster to the next stage of breakdown and replacement. Significantly, alterations to the occlusal anatomy may lead to changes in occlusal harmony and the introduction of undue stress on remaining cusp inclines, deflective inclines and functionally opening contacts—all of which will speed the decline and may lead to periodontal problems as well.

Gold remains the material of choice for long-lasting restorations, but is both relatively expensive and unaesthetic. Composite resin, like amalgam, offers no answer to this problem because neither its resistance to occlusal load nor its long-term adhesion to dentine are satisfactory at present.

While it is not suggested that glass-ionomer cement offers any substantial change, it does provide the opportunity for introducing a modified cavity design for the treatment of the initial lesion that may lead to conservation of a considerable amount of remaining unaffected tooth structure. Such *minimal cavity* designs should be regarded as a first stage prior to the more conventional designs that may still be required later in the downward disintegration of tooth structure.

The advantages of the glass-ionomer cements for such restorations can be listed as follows:

- minimal removal of sound tooth structure is required for access and convenience form;
- there will be minimal alteration to occlusal and proximal tooth anatomy;
- the cement flows freely and is simple to place;
- the adhesion and ion exchange with tooth structure unite and reinforce remaining enamel and dentine, and restore physical strength;
- continuing fluoride release enhances caries resistance;
- it will be easy to maintain aesthetics.

It must be emphasized that the concept applies only to the new lesion—and then only in the early

stages of progression of the caries into the dentine. It works best in the presence of routine systemic or topical fluoride, because this leads to better physical properties in the enamel. Involvement of the enamel in the carious lesion should not be great. A suitable Class I lesion, for example, will show carious dentine beneath one section only of the fissure system, with the remainder of the occlusal surface still intact. The Class II lesion on the proximal surface of a posterior tooth will normally commence as an elliptical area of demineralization immediately beneath the contact area, and the contact with the adjacent tooth itself will not be involved. There may, in fact, be little or no cavitation in the enamel, even though there is radiographic evidence of advancing caries in the dentine. Under these circumstances there is no need to remove the demineralized enamel, because it can be remineralized through the presence of fluoride, both from the cement and topically applied. As the enamel breakdown extends, the need to involve it in the cavity design increases until, eventually, the marginal ridge becomes so weakened that a conventional design becomes necessary.

Each new lesion should be explored and entered with a minimal cavity design in mind. Having developed access and convenience form, a decision can be made on the design to be followed. If the marginal ridge is still intact or the occlusal enamel is not unduly undermined, the minimal cavity may be accepted as complete and restoration undertaken. On the other hand, if the destruction is too great, the minimal concept may have to be abandoned and a conventional design employed. This progression is sensible and acceptable, because the minimal design does not require removal of any tooth structure that would not be involved in a conventional design.

If, upon completion of the restoration, there is any doubt concerning the ability of the glass-ionomer cement to withstand the occlusal stress, or the surrounding enamel requires further support, the cement can be cut back and laminated with composite resin. It is essential to *use a cement that is radiopaque so that the* restoration can be monitored in the future. The dual cure cements are the logical choice, because they flow readily, adapt well to the cavity, are radiopaque and have superior physical properties.

Breakdown at a later date will generally not occur because of recurrent caries but only through failure of enamel. Repair of a failed marginal ridge, for example, can often be carried out quite simply with minimal destruction of remaining tooth using composite resin laminated to the existing glass-ionomer cement.

Cavity designs

The following is the classification for *minimal cavities:*

- Class I/fissure seal
- Internal fossa cavities (tunnels)
  Class II occlusal approach
  Class II proximal approach
  Class III buccal or lingual approach

The design of the minimal cavity will be predicated to a large degree on the pattern of the carious lesion. Typical lesions are shown in Figures 6.1 and 6.19–6.22. Note the relatively limited entry and slow progress through the enamel in both the Class I and II lesions, followed by dentine involvement over a broader area. Progress through the dentine follows the curve of the tubules towards the pulp, and, particularly in the Class II cavity, this takes the lesion down and away from the contact area and marginal ridge. Further involvement towards the occlusal represents a later stage of development, by which time, generally, the contact area will also be involved.

The theory of 'infected dentine' and 'affected dentine' in the advancing lesion is also relevant to this cavity design. It is accepted that demineralization and softening of the dentine is always some distance in advance of the bacterial invasion and that removal of the infected dentine alone is sufficient to arrest progress. This means there is no need to remove all discoloured and softened dentine. It is sufficient to develop clean walls around the periphery of the lesion, leaving relatively bacteria-free dentine over the axial wall or pulpal floor. If the margin can now be completely sealed against ingress of further bacte*ria or bacterial nutrients from the oral environ*ment, the caries will not progress, and the softened dentine will remineralize. This process will be enhanced by the presence of the fluoride that is available from the cement.

Cavity designs can be discussed with the foregoing in mind.

Figure 6.1

An extracted tooth has been sectioned to show three different carious lesions and the direction of penetration of the advancing caries. Note the two stages of the Class I occlusal lesions. On the left the caries has only just penetrated through the fissure and entered the dentine, but on the right the pulp is now involved. The penetration by the caries is twice as deep as it is wide and has followed the direction of the dentinal tubules. The proximal lesion on the left has entered the enamel on a narrow front and then progressed inwards and downwards along the path of the dentinal tubules. This pattern of attack is significant in the design of cavities that are intended to remove caries only and minimize the loss of further tooth structure.

Class I/fissure seal

The concept of the fissure seal, as discussed by Simonsen and others, is particularly sound in a newly erupted tooth. Before a deep fissure becomes partially occluded by plaque and pellicle, and before the advance of a carious lesion into dentine, sealing a fissure with a resin sealant has an acceptable clinical history. It has been shown that a glass-ionomer cement will also successfully occlude such a fissure and will seal through chemical union with the enamel. The cement will also release fluoride. It should be noted, however, that neither a resin nor a glass-ionomer cement will flow into a fissure beyond the point where the fissure narrows down to approximately 200 µm in width (Figures 6.3 and 6.4). Therefore retention of both materials depends upon adhesion to the enamel at the entrance to the fissure rather than mechanical interlocking into the complexities of the fissure.

The Class I/fissure seal combination restoration using glass-ionomer cement represents the next step in treatment of a Class I lesion, and is designed to minimize the tooth destruction and weakening effect of the standard cavity design prepared for the placement of amalgam or composite resin. As the patient ages, an unsealed fissure may become susceptable to a newly initiated attack of active caries. The walls of the fissure will demineralize, and dentine involvement may follow rapidly, particularly in relation to a relatively small defect in an otherwise sound fissure system. Once the lesion reaches the dentine, the speed of advance may be affected by the high hydraulic pressure that can build up within the crown of the tooth during mastication, and, particularly where the enamel is well fluoridated, the lesion can be well advanced before the enamel roof collapses. The lesion may be evidenced only by a colour change on the occlusal surface or radiographically.

Often under these circumstances, the remaining fissure system will be sound and not involved. However, prudence may suggest that minor apparent defects should be explored before sealing the entire system. The material of choice

for this restoration is glass-ionomer cement because of its ability to flow into and seal narrow conservative cavities as well as its fluoride release. If the main enamel lesion is too extensive and there is doubt about the ability of the cement to withstand the occlusal load, it can be cut back conservatively and laminated with composite resin (Figures 6.11–6.16).

Instruments required (see Box E, page 139)

- Small tapered diamond stone at intermediate high speed (40 000 revolutions/min) under air/water spray, to open into the carious lesion.
- Very fine diamond point, to follow out the fissures.
- Small round burs, sizes 1/011–016, for caries removal.

Preparation and restoration

- Use a small tapered diamond bur at intermediate high speed under air/water spray to open into the lesion and gain access and visibility.
- Use a very fine tapered diamond to explore the remaining fissures as required to make sure there are no other similar lesions that did not show on the radiograph.
- Remove remaining infected dentine with hand excavators or small round burs at slow speed.
- Use binocular loupes, good illumination and disclosing solutions as required. Do not advance pulpally any further than essential, but develop clean dentine walls around the entire periphery.
- Condition the cavity as prescribed.
- Restore with a dual cure glass-ionomer cement for preference because of the superior physical properties and radiopacity. An auto cure is satisfactory, but the setting characteristics and water balance must be taken into account and radiopacity is mandatory.
- Place the cement with a syringe to ensure positive placement into the narrow fissures. When using an auto cure cement, use a small piece of lead foil cut from the back of a radiograph packet as a matrix to apply positive pressure.
- Cut back the cement and laminate with composite resin only if there is doubt about the ability of the cement to withstand the occlusal load.

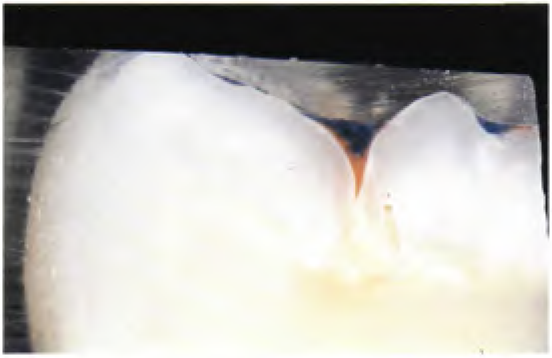


Figure 6.2

Section through the crown of an extracted tooth, showing a simple, open-fissure pattern with wide access that has been restored to its full depth with a glass-ionomer cement (dyed red and blue).

Figure 6.3

Section through an extracted tooth, showing the restriction part way down the fissure. This is a common problem, which limits the ability of a fissure seal to penetrate to the full depth of a fissure and may lead to failure. Note the demineralization along the walls and at the base of the fissure. Sealing the entry to the fissure will probably arrest this activity, but caries in the dentine cannot be assessed without exploration.

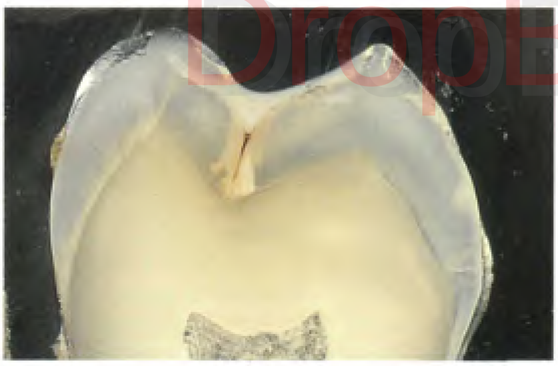


Figure 6.4

Section through a molar tooth that has been restored with a resin fissure seal. Note that the resin has not penetrated into the fissure beyond the point where the fissure is 200 μm wide (cf. Figure 6.3).

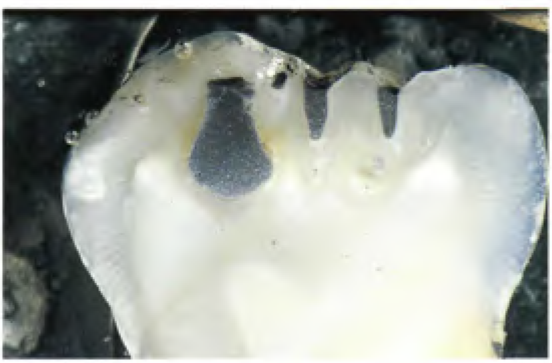


Figure 6.5

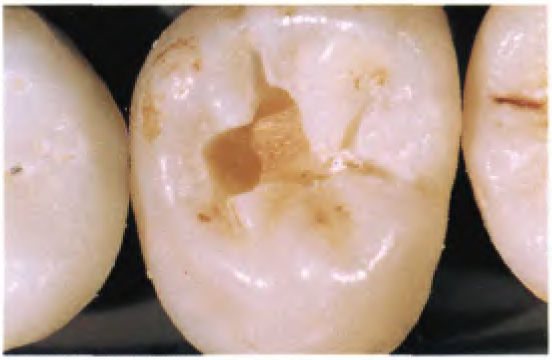
A further specimen sectioned mesio-distally following restoration with a cermet cement (see Figures 6.6–6.10). There are two minor fissures opened very conservatively, with a third opened sufficiently to allow removal of a small area of caries.

Simulated placement

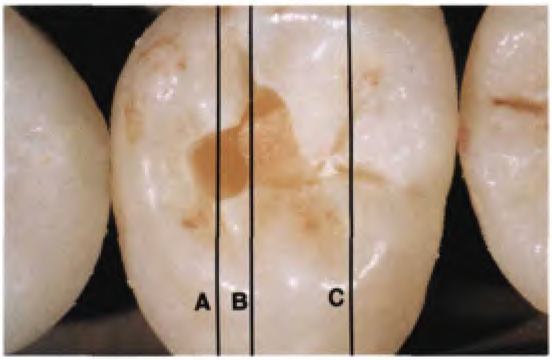
Class I/fissure seal

Figure 6.6

The occlusal surface of an extracted third molar, showing the typical convoluted fissure pattern. The central fossa will catch a fine probe, and it is reasonable to expect to find caries beneath. The remaining fissures are difficult to judge, and should be explored.



a



b

Figure 6.7

(*a*) Preparation of the cavity in the tooth shown in Figure 6.6 revealed a moderate amount of caries in the central fossa and minor involvement of the fissures radiating out across the occlusal surface. These were opened very conservatively with a very fine diamond point, without completely penetrating the enamel (see Box E, page 139). Having determined that these fissures were free of caries, the cavity was restored with a cermet cement. (*b*) The tooth was sectioned three times in a bucco-lingual direction for further examination (Figures 6.8–6.10).

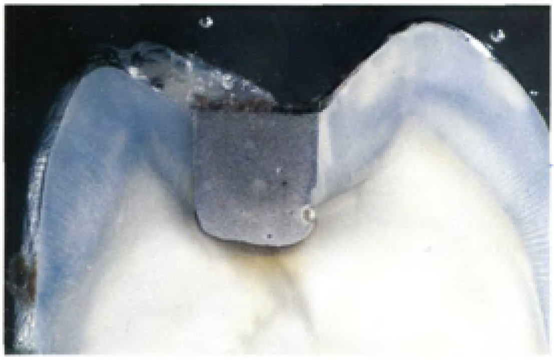


Figure 6.8

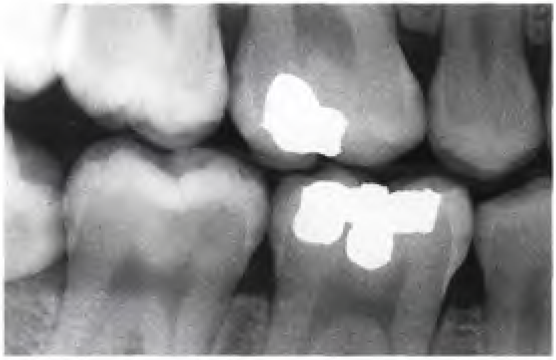
Slice A shows the mesial pit, which was carious and has been satisfactorily restored with the cement.

Figure 6.9

Slice B runs along the buccal fissure, and shows the way it is ramped up to the occlusal surface without fully penetrating the enamel.

Figure 6.10

Slice C crosses the two distal fissures, and confirms that the enamel is again not penetrated and has been satisfactorily sealed with the cement.



Clinical placement

Class I/fissure seal—dual cure cement

Figure 6.11

A bitewing radiograph showing a deep lesion beneath the occlusal fissure of the lower right second molar in a patient aged 25 years.

Figure 6.12

Occlusal view of the same tooth, showing the limited extent of the enamel involvement.

Figure 6.13

The completed cavity being conditioned with 10% poly(acrylic acid) for 10–15 seconds. At the deepest section the cavity was 8 mm deep. Note the minimal involvement of the remaining fissures, which were explored very conservatively with a very fine diamond to ensure there was no further caries present.

Figure 6.14

The cavity was restored with a dual cure cement and light-activated for 40 seconds from the occlusal. Depth of penetration of the light was expected to be 4 mm, but the remaining cement will set quite rapidly via the usual acid/base reaction. Alternatively, the cement may be built and light-activated incrementally. As a moderate area of the occlusal surface was involved, the load-bearing area was cut back immediately, ready for lamination.

Figure 6.15

The enamel margins only were acid-etched, and the occlusal surface was restored using the lamination technique with composite resin.

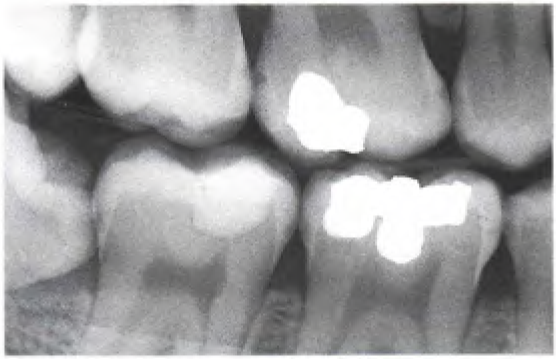


Figure 6.16

A bitewing radiograph showing the completed restoration. Note the difference in radiopacity between the cement and the dentine. Also, a small amount of affected dentine was left on the pulpal floor to avoid a possible pulp exposure. As the cavity is completely sealed, the dentine is expected to remineralize.

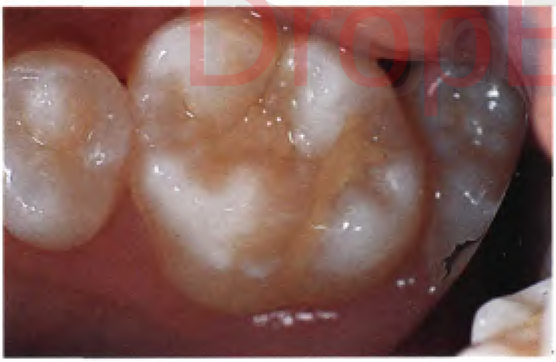


Figure 6.17

A fissure seal placed 10 years previously using an auto cure cement.

Figure 6.18

A fissure seal using an auto cure cement, photographed at 8 years.

Class II occlusal approach

As discussed above, the early proximal lesion on a posterior tooth will commence in the enamel immediately below the contact area because this is where plaque will accumulate and mature (Figures 6.19–6.22). Initially, the contact itself will remain plaque-free because of movement between the teeth, and the degree of fluoride already in the enamel will probably control the speed at which the enamel will actually undergo cavitation. Often, particularly in fluoridated communities, the enamel will remain relatively intact although demineralized until the dentine lesion is quite advanced. It will take up stain and become disfigured, but in the presence of further fluoride it may remineralize and become harder than the original enamel. Under these circumstances, it is unnecessary, and in fact undesirable, to remove this area of enamel, because removal will separate and further weaken the cusps.

As the lesion develops, some degree of breakdown and cavitation of the enamel will eventually occur, but this will remain confined to the area below the contact until it is quite advanced. There will generally be a zone of demineralized enamel surrounding the cavitation, but this remains capable of remineralization in the presence of a fluoride-containing cement. The contact area may remain sound and the marginal ridge may be quite strong, particularly following reinforcement with an adhesive cement.

Access to the carious dentine through the occlusal surface should be limited to the extent required to achieve visibility, and, where possible, should be undertaken from an area that is not under direct occlusal load. For most patients there is a fossa immediately medial to the marginal ridge, which is the most suitable region for initial entry and, in a normal occlusion, is not an area of occlusal contact. An examination of study models will often reveal the preferred position for access.

As far as possible, maintain the integrity of the marginal ridge. Explore the demineralized proximal enamel with care, and do not break it down unless this is essential. Discoloured and demineralized enamel can remain undisturbed unless it is very friable and actually cavitated. If there is any doubt about the safety of the adjacent tooth, place a short length of a metal matrix strip interproximally to protect it and support the matrix with a wooden wedge. It is unnecessary to wedge firmly, because the contact will still be viable and does not need to be rebuilt.

The removal of carious dentine should be confined to removal of infected dentine only and the development of clean sound dentine walls around the circumference. Affected, demineralized dentine on the axial wall may be left behind, particularly if there is a risk of pulp exposure if it is disturbed. No retentive elements are required in the design, because the cement will be retained through adhesion.

The cement most suitable for the restoration will be radiopaque with good physical properties. A dual cure cement is satisfactory, providing it can be adequately light-activated. If the occlusal area involved is large or under heavy occlusal load, it may be desirable to cut the cement back about 2–3 mm and laminate the surface with composite resin. This will reinforce both the cement and the marginal ridge through the acid-etch union of the resin to the enamel.

Instruments required (see Box E, page 139)

- Small, tapered diamond stone at intermediate high speed (40 000 revolutions/min) with air/water spray, to open the occlusal enamel.
- Small round burs, sizes 1/011–016, for caries removal.
- Long-shank bur for difficult access.
- Access for hand instruments is limited, but the MC 1 double-bladed chisel may be useful.

Preparation and restoration

- Use a small tapered diamond stone at intermediate high speed under air/water spray, and enter from the fossa immediately medial to the marginal ridge. Angle the stone towards the lesion, and progress inwards and gingivally until the lesion can be identified.
- Upright the stone towards the marginal ridge, and lean it buccally and lingually to develop a funnel-like approach with a triangular entry from the occlusal to improve visibility and access. Good illumination and magnification are desirable.

- Use small round burs at slow speed to remove infected dentine from the full circumference of the lesion. Take care on the axial wall to protect the pulp. Use caries-disclosing solutions as required to remove infected dentine, but leave affected dentine undisturbed.
- Carefully examine the enamel wall. If it is not cavitated, do not prepare it any further. If there is cavitation, protect the adjacent tooth with a metal matrix band and remove friable enamel rods carefully with a small hand instrument such as the MC I chisel. Leave the matrix in place during restoration.
- Condition the cavity and restore with the selected cement. Place the cement with a capsule or a disposable syringe to optimize adaptation to the cavity walls, and, if using an auto cure cement, use a small piece of lead foil from the back of a radiograph as a matrix to apply additional pressure.
- Cut back the cement and laminate the occlusal entry with composite resin only if there is doubt about the ability of the cement to withstand the occlusal load.

Class II proximal approach

A further very conservative approach to the restoration of a proximal lesion can be achieved on limited occasions only when the proximal surface of a posterior tooth becomes accessible at the time of cavity preparation in an adjacent tooth. The lesion may have been revealed through radiographs or may be noted only during cavity preparation. The adjacent cavity will normally need to be of reasonably generous proportions to allow room for manoeuvre, but when such an approach is possible, it leads to considerable conservation of natural tooth structure (Figures 6.53–6.58).

In view of the direction of the progress of the carious lesion through the enamel and down the dentine tubules (Figure 6.22), it is not difficult to clean the cavity, trim the enamel walls and eliminate infected dentine.

As the entire restoration will probably be covered and disguised by the adjacent tooth, it is necessary to use a radiopaque cement, and, in view of probable difficulties in access for light activation, the cement selected should be an auto cure.

Instruments required (see Box E, page 139)

- A small tapered diamond stone at intermediate high speed (40 000 revolutions/min) under air/water spray to open the enamel lesion.
- Small round burs, sizes 1/011–016, for caries removal.
- Use a long-shank bur for difficult access.
- Access for hand instruments is limited, but the MC I double-bladed chisel may be useful.

Preparation and restoration

- Enlarge access into the enamel lesion using a small tapered diamond stone at intermediate high speed under air/water spray with good illumination and magnification (Figures 6.59–6.62).
- Remove the infected dentine with small round burs at slow speed. Burs with long shanks may be required for correct bur placement. Use disclosing solutions as required, and make sure the circumference of the cavity is completely clean to allow for adhesion.
- Condition the cavity, and use a short length of mylar strip as a matrix, supported as required with a wedge.
- Restore using a radiopaque cement, such as a Type II.2 auto cure, so that it can be monitored radiographically in future.
- Contour and polish immediately prior to placing the adjacent restoration.

Figure 6.19

The proximal surface of an extracted tooth, showing the contact area and a small area of demineralization immediately beneath.

Figure 6.20

The tooth shown in Figure 6.19 sectioned to reveal the penetration of the demineralization into the dentine. However, the enamel is not cavitated and may be remineralized. It is, therefore, unnecessary to break it down and remove it while restoring the carious dentine.

Figure 6.21

Another extracted tooth, showing a more advanced carious lesion below the contact area, which is already cavitated.

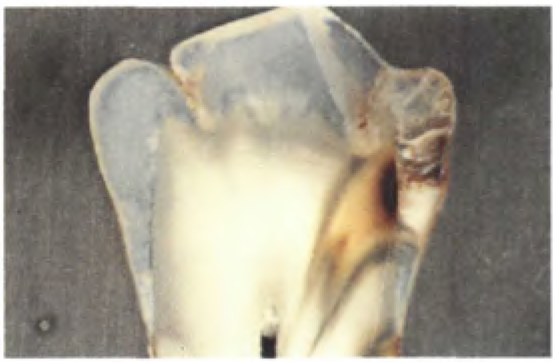


Figure 6.22

The tooth in Figure 6.21 has been sectioned, and shows the cavitation and the direction of the advance of demineralization down the dentine tubules. Infected dentine will not have progressed far beyond the enamel cavitation.

Simulated restoration

Class II—occlusal approach

Figure 6.23

There is a mesial carious lesion on this extracted tooth, which has been mounted to allow a simulated cavity to be prepared under 'clinical conditions'. Enter the lesion with a small tapered diamond stone at intermediate high speed, aiming at the approximate position of the carious dentine. Place a short length of a metal matrix strip to protect the adjacent tooth if it is at risk.

Figure 6.24

Having identified the caries, upright the same tapered diamond stone and lean it buccally and lingually to provide a 'funnelled' access to the cavity.

Figure 6.25

An occlusal view showing the outline to be achieved to provide convenience and access to the caries. Remove the infected dentine using long-shank small round burs. Carefully clean the walls, but be conservative with both the axial and the enamel wall. Use a disclosing solution as required.

Figure 6.26

Condition the cavity with 10% poly(acrylic acid) for 10–15 seconds, wash thoroughly and dry lightly. Do not dehydrate.

Figure 6.27

Place a short length of mylar strip or metal matrix band to act as a matrix for the cement. Support lightly with a wedge. Place the tip of the syringe to the bottom of the cavity and, to minimize air inclusions, continue to extrude cement while withdrawing the syringe.

Figure 6.28

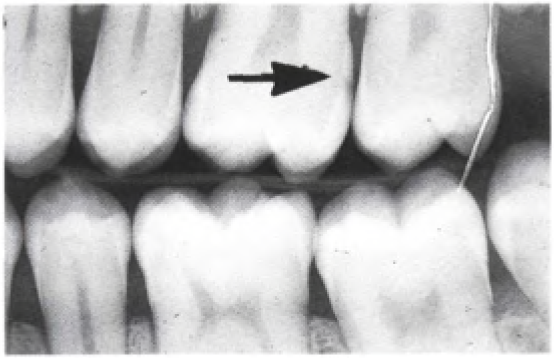
The completed restoration. If the occlusal load is unduly heavy, the cement can be cut back and laminated with composite resin.

Figure 6.29

The proximal surface of the tooth immediately after restoration. Note the amount of tooth structure retained because of the conservative approach. The presence of demineralized enamel is of no concern, because it will remineralize through the presence of the fluoride released from the cement.

Figure 6.30

The tooth has been sectioned through the restoration to show the extent of the cavity. Note the strength in the remaining marginal ridge as shown in the last two illustrations.



Clinical placement—auto cure cement

Class II—occlusal approach

Figure 6.31

A radiograph reveals a small carious lesion at the distal of the upper-right first molar.

Figure 6.32

The access cavity on the occlusal is approximately triangular in outline, maintaining the strength of the marginal ridge. The caries is cleaned out with a small, round bur, and then the cavity is conditioned with 10% poly(acrylic acid) for 10–15 seconds.

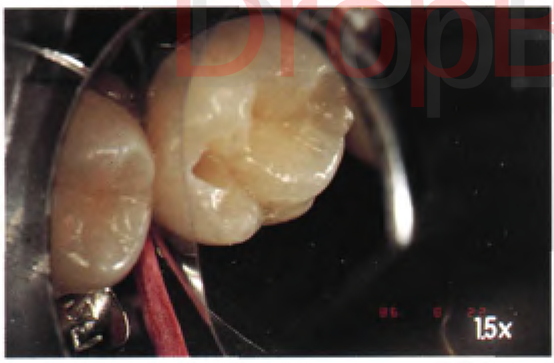


Figure 6.33

A matrix is wedged firmly into place using a short length of mylar strip.

Figure 6.34

The cement is placed in at least two increments, and tamped into place with a small plastic sponge. A small soft-metal matrix is placed over the occlusal to force the cement into place and left until it has set.

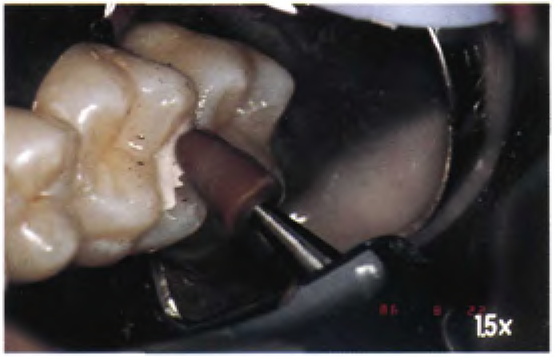


Figure 6.35

Because the cement used is a fast-setting cement, 5 minutes from the start of mix, the excess is trimmed and the cement polished with mild abrasive cups and points under air/water spray.

Figure 6.36

Radiograph of the completed restoration. If aesthetics is of concern, the occlusal 2 mm can be trimmed back and composite resin applied using the sandwich technique.

Class II tunnel through an existing cavity

Figure 6.37

A bitewing radiograph reveals a small carious lesion at the distal of the lower-left molar. The existing occlusal Class I amalgam is classified as requiring replacement, so the distal lesion will be approached through the occlusal cavity.

Figure 6.38

The amalgam has been removed, and the carious lesion identified and cleaned. Access under these circumstances is straightforward, and visibility is not a problem. The metal matrix was placed early to avoid damage to the adjacent tooth during cavity preparation.

Figure 6.39

A cermet cement has been syringed into the cavity and tamped into place with a small plastic sponge. Note the excess cement that has extruded beyond the matrix, thus ensuring good adaptation to the enamel. The same cement has been spread on the floor of the cavity as a lining.

Figure 6.40

Amalgam has now been replaced in the main cavity, since it was considered too large to be restored in glass-ionomer cement alone.

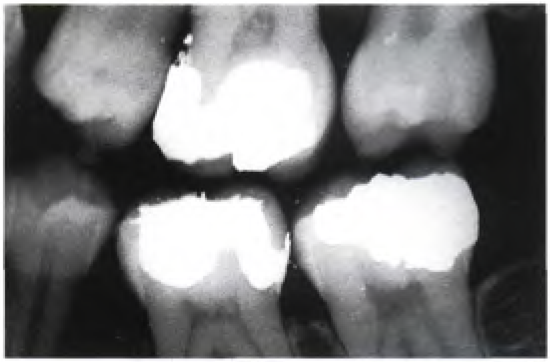


Figure 6.41

Radiograph showing the completed restoration.

Longevity in tunnel restorations

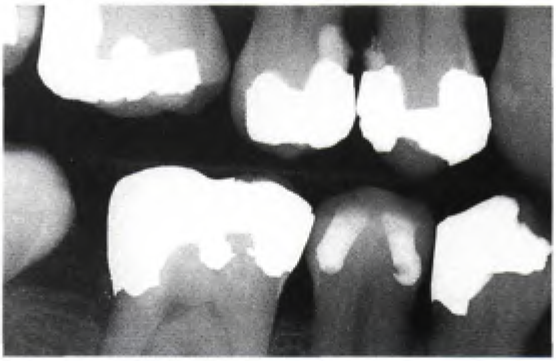


Figure 6.42

a (a) Tunnel restorations were placed approximately 3 years ago in the lower-right second bicuspid. It became necessary to replace the amalgam restoration in the mesial of the first molar.

b (b) On removing the amalgam from the first molar, the distal of the second bicuspid was revealed. Note the apparent stability of the enamel following remineralization, which arose, at least in part, from the glass-ionomer cement in the tunnel restoration.

Figure 6.43

A Class II occlusal approach tunnel restoration in the distal of the lower-left second bicuspid. It has been in place for 3 years, and the amalgam restoration now has to be replaced because the mesio-lingual cusp is split. A bitewing radiograph shows that there is no further caries and the proximal enamel is relatively intact.

Figure 6.44

The amalgam has been removed to reveal the proximal surface of the second bicuspid. Note the very limited extent of the enamel involvement in the tunnel cavity. The enamel appears to have remineralized and, although stained and disfigured, is sound.

Figure 6.45

Two Class II occlusal approach restorations in a cermet cement in adjacent teeth that have been in place for 6 years.

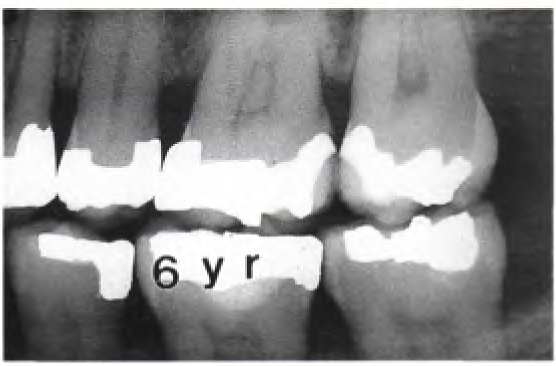


Figure 6.46

A bitewing radiograph of the restorations shown in Figure 6.45 indicates no change over that period of time.

Class II tunnel – occlusal approach – dual cure cement

Figure 6.47

A bitewing radiograph shows a proximal lesion in the distal of both the first and second deciduous molars.

Figure 6.48

An occlusal view of the lesions before treatment commenced.

Figure 6.49

The completed cavity preparations. Note that in the first molar there is still enamel proximal contact because only the demineralized tooth structure has been removed and the walls of the cavity cleaned. The cavity in the second molar has been designed as an occlusal approach tunnel.

Figure 6.50

A short length of mylar strip has been lightly wedged in place to act as a matrix for each restoration. The cavities were conditioned, washed and dried lightly, then restored with a dual cure cement.

Figure 6.51

An occlusal view of the completed restorations. Note the excellent colour match.

Figure 6.52

a (*a*) A bitewing radiograph showing the finished restorations.

b (*b*) 15 months after placement, the teeth were removed to allow eruption of the two bicuspids. The second molar has been sectioned to show the design of the 'tunnel cavity' preparation.

c (c) The proximal surface of the second molar prior to sectioning. Note an apparent lack of progress in the enamel lesion over the past 15 months. The adjacent first permanent molar showed no surface demineralization.

Simulated restoration

Class II—proximal approach

Figure 6.53

Restoration of a lesion in an extracted tooth. A large cavity has been opened in the mesial of a first molar, revealing a proximal lesion in the distal of the second bicuspid.

Figure 6.54

A radiograph confirms the extent of the lesion.

Figure 6.55

The presence of the adjacent tooth limits the angle at which the bur can be manipulated in the handpiece. However, since the caries will penetrate down the dentinal tubules away from the occlusal, this angle of approach generally coincides with the progress of the lesion (Figure 6.1). The full extent of the enamel lesion can be removed, and the carious dentine can be dealt with.

Figure 6.56

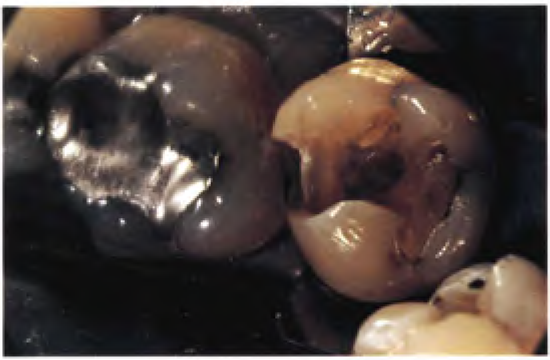
The cavity can now be conditioned and restored with a radiopaque fast-setting cement. Five minutes from the start of mix, the cement can be contoured and polished completely.

Figure 6.57

A matrix can now be placed on the adjacent molar, and the restoration of choice carried out.

Figure 6.58

The assembled teeth have been sectioned mesio-distally to show the design of the tunnel cavity. Note that the design of the cavity follows the dentinal tubules and that this coincides with the direction of penetration of the caries (Figure 6.1).



Clinical placement

Class II—proximal approach

Figure 6.59

On opening the mesial cavity in an upper-right second molar, a lesion became obvious in the distal of the first molar. Radiographically, there was very little penetration into the dentine, and so a proximal approach was carried out.

Figure 6.60

The completed cavity, showing that the enamel wall is caries-free.

Figure 6.61

A short length of mylar strip is used as a matrix, and, after conditioning the cavity, this is wedged into place and the cement is syringed and tamped into the cavity.

Figure 6.62

The matrix can be removed at 4 minutes from the start of mix, and the cement trimmed and polished immediately.

Class III buccal or lingual approach

There are some circumstances under which it may be prudent and conservative to enter a carious lesion on the proximal surface of a posterior tooth from either the buccal or the lingual rather than from the occlusal or the proximal. The resultant cavity is classified as a Class III tunnel because it closely resembles such a cavity in an anterior tooth, and the problems presented are similar.

The decision concerning the side of entry will be dictated primarily by the position of the lesion and secondarily by the need for access and convenience. The cavity design is appropriate generally in the ageing patient where a degree of gingival recession has exposed the root surface and a carious lesion has developed well gingival from the contact area.

It is, of course, possible to approach an initial lesion immediately under the contact area in a young patient with this design. However, the closer the cavity is to the marginal ridge, the more likely it is that the ridge will fail at a later date. The lesion in the older patient will be well below the contact area, and remaining tooth structure is therefore less likely to fail subsequently (Figures 6.63–6.66).

The problem will usually be related to root surface caries on an otherwise unrestored tooth or to an open margin on a crown, or it may be recurrent caries in relation to an overhanging margin on an old restoration. A careful history should be elicited, because such lesions are often related to a functionally opening contact, and this should be dealt with at the time of restoration by adjusting the occlusion.

The condition of the previous restoration will need to be carefully assessed. With an old amalgam, for example, the question may be whether to replace the entire restoration or develop a Class III tunnel. If the occlusion, proximal contour and contact and the margins are sound, it may be far kinder to an elderly patient to provide the minimal treatment in the form of a tunnel (Figures 6.67–6.74). For restoration of a lesion under a full crown the tunnel is only justified when the remaining margins are entirely acceptable and caries-free.

It is particularly important when dealing with root surface caries to differentiate between infected and affected dentine, and a disclosing solution may be of value. It is only necessary to remove the infected dentine and leave any further softened, demineralized, affected dentine on the axial wall undisturbed to avoid the risk of a pulp exposure. The tissue compatability of glass-ionomer cement is such that a lining under the cement is unnecessary.

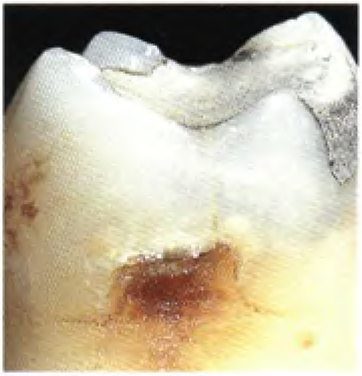
As it may well be difficult to monitor the restoration in the future without radiographs, it is recommended that a radiopaque cement be placed. Providing there is sufficient access for the correct positioning of an activator light, a dual cure cement is probably the material of choice.

Instruments required (see Box E, page 139)

- Small, tapered diamond stone at intermediate high speed (40 000 revolutions/min) with air/water spray, to open into the lesion at the expense of both tooth structure and old restoration.
- Small round burs, sizes 1/011–016, for caries removal.
- Long-shank round burs may be required for deep access.
- Round bur, size 1/011, for retention.
- Access for hand instruments is limited.

Preparation and restoration

- Enter the lesion from the buccal or the lingual as the position of the carious lesion dictates, using the small tapered diamond stone at intermediate high speed under air/water spray.
- Begin slightly occlusal to the lesion, and move interproximally and gingivally until the lesion is clearly visible. Sacrifice sufficient tooth structure or old restoration to allow access and convenience form without unduly weakening the marginal ridge.
- Use small round burs at slow speed to remove all infected dentine and develop clean walls around the entire circumference. Leave the axial wall, even though it is demineralized.
- If possible, retain the wall at the opposite side from the entry, to provide a positive finishing line for the restoration.
- Use a short length of a metal matrix to protect the adjacent tooth while working. Wedge the matrix carefully when placing the cement.
- Restore using a radiopaque cement. If access is available for correct placement of the activator light, use a dual cure cement.
- Trim and contour carefully after placement to ensure there is no overhang or overcontour.



Simulated restoration

Class III—buccal approach

Figure 6.63

A root surface caries lesion on the distal of an extracted molar tooth.

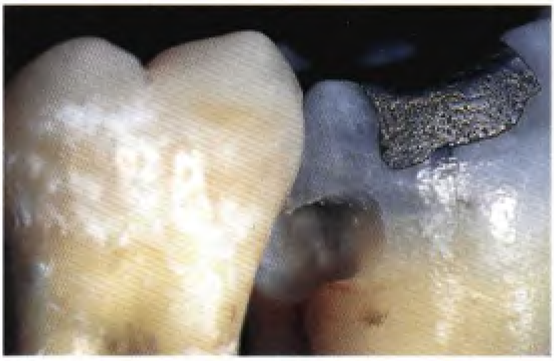


Figure 6.64

The tooth has been set up in a simulated situation and the cavity prepared. Open initially with a small tapered diamond, beginning from just occlusal to the lesion. Clean the walls with long-shank round burs, and retain the wall opposite to the entry if possible.

Figure 6.65

The completed cavity from the distal, showing retention of the lingual wall and the approach from the occlusal at the entry side.

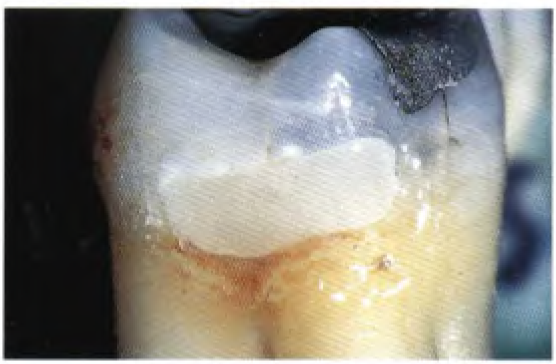


Figure 6.66

The completed restoration using a dual cure cement.

Clinical placement

Class III tunnel, buccal approach—auto cure cement

Figure 6.67

An upper-right first molar has over-erupted, and now shows root-surface caries beyond the gingival margin of an old amalgam. The amalgam is considered to be otherwise satisfactory, so a buccal approach to the carious lesion is the method of choice.

Figure 6.68

The initial approach is at the expense of enamel and the old restoration only to determine the extent of the problem.

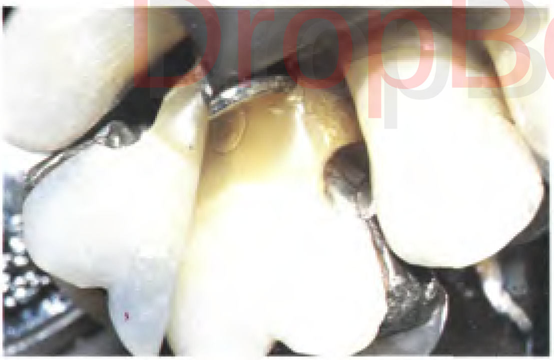


Figure 6.69

Having determined the extent of the problem, the cavity outline is completed, including further removal of some of the old amalgam to gain full access.

Figure 6.70

A simulated cavity on a similar extracted tooth, to demonstrate the extent of the cavity design. Retention has been provided with shallow grooves in the occlusal and gingival walls, and the lingual wall has been retained as far as possible to act as a base against which to place the cement.

Figure 6.71

A short length of mylar strip is wedged into place as a matrix, and the cavity is conditioned, washed and dried.

Figure 6.72

The cement is tamped into place in at least two increments, and at 6 minutes from the start of mix it can be trimmed and polished.

Figure 6.73

The same restoration shown in this series 7 years after placement.

Figure 6.74

A similar Class III tunnel restoration 6 years after placement. This restoration was briefly revealed through the loss of the crown on the second bicuspid.

Class III tunnel, buccal approach—dual cure cement

Figure 6.75

A moderately extensive root surface caries lesion at the mesial/gingival margin of the upper left first bicuspid.

Figure 6.76

The cavity is conditioned for 10–15 seconds, washed and dried (but not dehydrated) before placement of the cement.

Figure 6.77

The completed cavity design. Note that access is gained at the expense of the tooth structure towards the occlusal without weakening the marginal ridge. A short length of mylar strip is placed and supported with a wedge to act as a matrix. The cement will be light-activated from both the buccal and the lingual for 20 seconds.

Figure 6.78

The finished restoration immediately after removal of the rubber dam.

7 Instructions for dental assistants

As with all dental materials, the dental assistant plays an important part in correct handling and clinical success. This chapter is therefore designed to help the dental assistant to understand the handling requirements of the glass-ionomer cements. As all three types are essentially the same from a chemical point of view, they can all be discussed under the same headings. There is nothing particularly difficult in the storage, dispensing or mixing of these materials, but precision and understanding are a necessary part of good dental assisting, and the following points should always be observed when handling the glass-ionomer cements.

Storage of cement in bottles

Powders or liquids supplied by different manufacturers or of different types must **never** be interchanged. They are all different, and an interchange of components will destroy properties.

Because the glass-ionomer cements are water-based, they will always be subject to further loss or uptake of water. Therefore both powder and liquid bottles should remain firmly closed at all times (Figure 7.1).

With some of the materials available, the liquid supplied is a type of poly(alkenoic acid). With others, the poly(alkenoic acid) has been dehydrated and is already incorporated in the powder. In this case the liquid will be water or a solution of tartaric acid.

If the liquid being used is poly(alkenoic acid), it will be subject to water uptake, and the bottle should remain firmly closed. In addition, it will tend to age and thicken over a period of time. Within 12 months of manufacture, the viscosity may increase to the stage where it flows very slowly and is difficult to dispense accurately. The liquid can be thinned down as follows:

Figure 7.1

Figure 7.2

- Immerse the entire bottle, with the lid on, in water at 75°C (167°F) for 15 minutes. Stand the bottle in a rubber bowl and let water from the hot tap run over it. The bottle will float on the top of the water, but the temperature will be about right (Figure 7.2).
- Test it at 15 minutes to see that the viscosity has come back to normal.
- Let it cool again before using it.

The liquids should never be stored in the refrigerator, but storage of the powder and the mixing slab in the refrigerator will marginally lengthen working time (Figure 7.3). The difference will not be great, but, where the office is not air-conditioned, or the average temperature is high, it is worthwhile because it will take the pressure off the clinical handling.

- Make sure that the slab is not below the dew point before dispensing the powder.
- Wipe it quite dry with a tissue, or there will be a small addition of water to the powder.

Figure 7.3

Hand dispensing of powder and liquid

If the capsulated varieties of cement are not available then hand dispensing must be carried out with great care.

- Read the manufacturer's instructions, which will generally suggest that the powder be fluffed up in the bottle first and a level spoonful extracted and dispensed onto the slab.
- Make sure that the spoon is full and that there is no excess powder on the back of the spoon or along the handle.
- Scrape the top of the spoon over the lip on the bottle, and be prepared to repeat the measure if there are obvious spaces in the powder (Figure 7.4).

Figure 7.4

If the liquid is poly(acrylic acid), it is difficult to dispense without including an air bubble in the drop, particularly as it becomes more viscous. Dispense in two distinct moves.

- Tip the bottle onto its side first and allow the liquid to run into the spout.
- If the liquid is provided in a translucent bottle, this can be readily observed. If the bottle is opaque, experience will dictate the length of time required.
- Invert completely before dispensing a drop (Figures 7.5 and 7.6). Generally, there will now be a clean drop dispensed, with no air bubble included.

If the liquid is water or dilute tartaric acid, care must be taken to dispense only one drop at a time.

- Apply gentle pressure to the rubber cuff at the neck of the bottle, since a vigorous squeeze may produce a squirt rather than a drop (Figure 7.7).

Figure 7.5

Figure 7.6

Figure 7.7

Mixing by hand

Most manufacturers provide a paper pad on which to mix the cement. This is quite satisfactory, provided that the liquid is not left standing on the pad for longer than one minute, because water is likely to soak into the pad from the liquid and alter the powder/liquid ratio. Use of a glass slab is to be recommended, because it will not affect the water balance, it can be chilled in the refrigerator and working time can thus be slightly extended (Figure 7.8).

The principle of mixing is simply to fold the powder into the liquid in the shortest possible time (Figures 7.9–7.11).

- Do not spread the mix around the slab and do not spatulate heavily. The object is to wet the surface of each particle of glass powder to develop the matrix—not to dissolve the entire particles in the liquid (Figure 1.3). This means that either a steel or a plastic spatula can be used, as long as it is handled correctly.
- Divide the powder into two parts. Fold in the first half within 10–15 seconds, then add the second half and incorporate it entirely within the next 15 seconds. Keep the mixing to a small area of the slab only, and do not continue to spatulate once the powder is all incorporated.
- Transfer immediately into a disposable syringe.

Figure 7.9

Figure 7.10

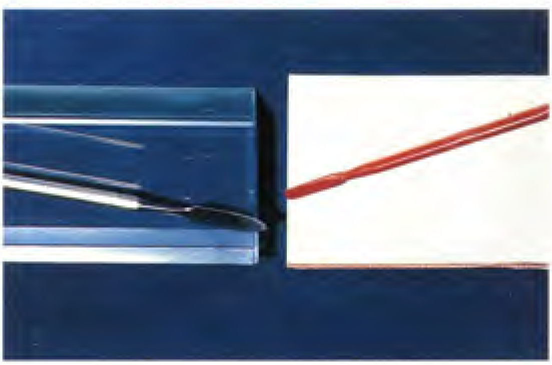


Figure 7.8

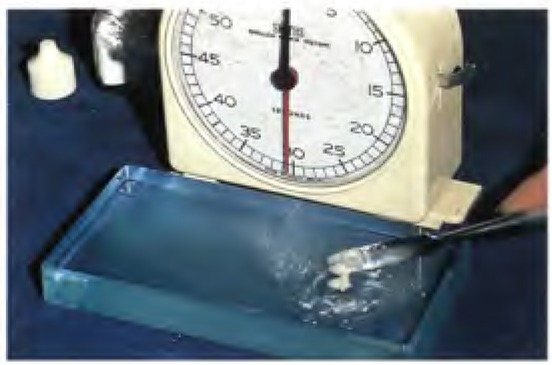


Figure 7.11

Mixing of capsules

In those cements dispensed in capsules the liquid component is generally a rather viscous poly(alkenoic acid). This means that care must be taken in collapsing the capsule to see that all the acid has been squeezed out of its sachet.

- If the capsule is activated in a press, apply adequate pressure to the capsule and maintain that pressure for 3 or 4 seconds before releasing and placing the capsule in the machine for mixing (Figure 7.12).
- If the capsule is activated by rotating one half against the other, use adequate force to collapse it totally (Figure 7.13).
- Note the prescribed mixing time and do not vary it. Use an ultra-high-speed mixing machine, that is, one capable of at least 4000 cylces/min. Machines capable of 3000 cycles/min are not suitable for mixing these cements. It is important to realize that there may be considerable variation between different types of machine, and even some variation within machines of the same make. This means that results are not necessarily standard (see page 10).
- Learn to recognize the time for 'loss of gloss' from the cement mixed by your machine, because placement of the cement after that time will result in loss of adhesion and deterioration of physical properties in the final restoration. To test the machine, make a trial mix and time it from the beginning of mix. Express the mix into a pile on a glass slab and watch it carefully. Although difficult to define, there is a point at which the gloss will have gone entirely from the surface. Normally this point should be reached at about 2 minutes from the start of mix.

The time for mixing usually recommended is 10 seconds in a machine capable of 4000 cycles/min. Extension beyond this time up to 15 seconds will reduce working time significantly, and is clinically undesirable. Reduction of mixing time to 7 seconds may extend working time to about 2.5 minutes, but there is a risk of having unreacted liquid still present (see Box A, page 10).

Figure 7.12

Figure 7.13

- Immediately the capsule is removed from the machine, it may be necessary to bend the spout of some makes of capsule through about 45 degrees for ease of placement of the cement into difficult corners (Figure 7.14).
- Deliver the capsule promptly to the operator. Working time is not long, because of the small temperature rise caused by the high energy of the machine-mixing.

Figure 7.14

Correct consistency for hand-mixed cements

Type I: luting cements

Type I luting cements will be mixed at a powder/liquid ratio of about 1.5 : 1 and will therefore string up approximately 3–4 cm from the slab (Figures 7.15 and 7.16).

Figure 7.15

Figure 7.16

Figure 7.17

Figure 7.18

Type II.1: restorative aesthetic cements

Type II.1, both dual cure and auto cure, restorative aesthetic cements will string only 1 cm off the slab, but must retain a glossy surface (Figures 7.17 and 7.18).

Type II.2: restorative reinforced cements

Type II.2 restorative reinforced cements will have the same powder/liquid ratio as the Type II.1 restorative aesthetic cements. Therefore they will string up approximately 1 cm off the slab, and must retain a glossy surface. Working time for the hand-mixed variety will be very short (since these cements are generally capsulated, no illustration is shown).

Type III: lining cements

For **lining** amalgams, the powder/liquid ratio will be only 1.5 : 1 for both dual cure and auto cure cements, so the cement will string up 3–4 cm off the slab (Figure 7.19).

For **basing out** composite resins, the powder/liquid ratio will be 3 : 1 or greater, so capsulation is recommended. If hand-mixed, it will string out only 1–2 cm, but must retain a glossy surface (Figure 7.20). Working time will be quite short for the auto cure cement, but will be approximately 3.25 minutes for dual cure cements.

Figure 7.19

Figure 7.20

Methods of placement

Type I: luting cements

Apply with a short, stiff-bristled brush to both the restoration and the tooth (Figures 7.21 and 7.22).

Type II.1: restorative aesthetic cements

Apply for preference in a syringe, for positive placement and reduction of porosity. If hand-mixed, transfer into a Centrix-type disposable syringe (Figures 7.23 and 7.24).

Figure 7.21

Figure 7.22

Figure 7.23

Figure 7.24

Type II.2: restorative reinforced cements

Apply in a syringe and tamp into place using a small plastic sponge (Figure 7.25). If hand-mixed, transfer into a Centrix-type disposable syringe.

Figure 7.25

Type III: lining cements

To line a cavity

Apply with calcium hydroxide applicator, and flow into place (see Figure 5.8).

To place or base a dentine substitute

Apply with a syringe, and tamp into place with a small plastic sponge (Figure 7.25).

Clean-up procedures

- As soon as the cement has been used, and prior to its setting, completely immerse the slab and the spatula in water. It will then clean off quite readily. The longer it is allowed to set, the more difficult it will be to remove (Figures 7.26–7.27).
- If the cement has inadvertently been allowed to set on the slab or the instruments, there is no alternative other than to chip it off. Stand it in water for a while first; this will make it easier, but it will still be hard work.

Figure 7.26

Figure 7.27

8 Condensed instructions: all types

The following instructions are meant to be a brief resumé aimed primarily at the chairside dental assistant. They can be used in place of the printed instructions from manufacturers, which are often a little vague and on many occasions are clouded by the use of adjectives extolling the virtues of their particular product.

These instructions can be used as a ready reference for each of the types of material; they are brief enough to be kept in the operating room for ready reference by the assistant.

Type I: luting cements

Dispensing

The powder/liquid ratio is important. When dispensing the powder, follow the manufacturer's directions. In particular:

- Shake the bottle
- Spoon out the powder carefully.

It is very easy to:

- Have voids in the powder and therefore under-dispense
- Have spare powder on the back of the spoon or the handle and therefore over-dispense.

When dispensing the liquid:

- Turn the bottle horizontal for a moment, then pause before inverting completely to ensure dispensing a clean drop.
- Count the drops.

Mix half the powder at a time and complete the mix quickly. The chemical reaction begins **immediately**, and prolonged mixing will only break up the newly formed polymer chains and dissolve the powder.

Conditioning the tooth

Vital tooth

Having removed the temporary restoration and any remaining cement, just wash the tooth with air/water spray and lightly dry it. Do not dehydrate.

- Do not clean any further.
- Do not remove the smear layer.
- Seal the smear layer with a mineralizing solution or a dentine bond containing a poly(alkenoic acid).
- If you are relying on the adhesion between the cement and the dentine to retain the crown then **do not** cement the crown.
- The use of an adhesive cement will not compensate for a poor preparation.

Non-vital tooth

Having removed the temporary restoration and any remaining cement, condition the entire dentine, particularly in the posthole, with 10% poly(acrylic acid) for 10–15 seconds.

- Wash thoroughly with water, then dry with alcohol followed by a gentle air stream.
- Do not dehydrate the tooth.

Placement of the restoration

- Paint the cement onto the restoration with a small stiff bristle brush.
- Paint a little cement onto the tooth as well.
- Place the restoration and apply positive pressure until the margin is fully closed. Release the pressure and maintain a dry field.
- If using a fast-setting cement, further protection is not required.
- If using a slow-setting cement, varnish liberally with the manufacturer's waterproof varnish and wait until the cement is set.

Type II.1: restorative aesthetic cements

Dispensing

The powder/liquid ratio is important for both auto cure and dual cure cements.

Capsulated

The powder/liquid ratio is already set. Follow the manufacturer's directions carefully when activating the capsule.

Hand dispensing

When dispensing the powder, follow the manufacturer's directions. In particular:

- Shake the bottle
- Spoon out the powder carefully.

It is very easy to:

- Have voids in the powder and therefore under-dispense
- Have spare powder on the back of the spoon or the handle and therefore over-dispense.

When dispensing the liquid:

- Turn the bottle horizontal for a moment, then pause before inverting completely to ensure dispensing a clean drop.
- Count the drops.

Mix half the powder at a time and complete the mix quickly. The chemical reaction begins **immediately**, and prolonged mixing will only break up the newly formed polymer chains and dissolve the powder.

Conditioning the tooth

- To gain optimum adhesion, remove the smear layer, plaque, pellicle and any other contaminants to ensure that the dentine and enamel are in a clean condition ready for full chemical union.
- Alternatively, apply a mineralizing solution.

Prepared cavity

Apply 10% poly(acrylic acid) on a cotton pledget for 10–15 seconds only. Wash thoroughly with air/water spray for 20 seconds. Dry lightly. Do not dehydrate.

Erosion lesion

Clean lightly with a slurry of pumice and water. Wash thoroughly with air/water spray. Dry lightly. Condition with 10% poly(acrylic acid) for 10–15 seconds and wash again. Dry lightly. Do not dehydrate.

Placement of the restoration

- Apply the cement to the cavity promptly. Remember, it is already beginning to set.
- Use of a syringe is desirable because positive placement will minimize porosities and voids.
- Use of a matrix is desirable but not essential. The cement will set in the presence of air, but a matrix will apply presure and adapt the material more positively to the cavity floor and walls and minimize porosities and voids.

- **Note carefully:** Probably because of its chemical affinity to both tooth structure and the material of the matrix strip, the cement will not flow far in advance of the tip of the syringe. Therefore place the tip of the syringe right to the floor of the cavity, or right to the end of the tunnel. Begin to syringe and withdraw at the same time. When placing capsulated cements, it is possible to place incrementally and tamp each increment into position with a small plastic sponge.

Completion of the new restoration

Dual cure cements

- Light-activate for 20 seconds before removing the matrix.
- Light-activate for at least 20 seconds after removing the matrix.
- It is impossible to over-light-activate, but failure to completely activate can be dangerous.
- Carefully contour and polish after full activation under air/water spray using fine-graded polishing diamonds: **do not dehydrate.**
- Apply a low-viscosity resin glaze containing a poly(alkenoic acid).

Auto cure cements

- Type II.1 auto cure cements take at least 24 hours to achieve an acceptable degree of maturity. If aesthetics and physical properties are important, do not disturb for 24 hours.
- Approximately 4 minutes from starting to mix the cement, remove the excess cement from around the matrix, and confirm that it is set. Remove the matrix and immediately apply a liberal coat of a single-component, very low-viscosity, light-activated bonding resin.
- After application of the bonding resin, trim only if essential. Adjust the occlusion and remove overhangs as required.
- Apply more bond if required and activate with light. Do not disturb again for 24 hours.

Polishing

After 24 hours, polish as required—always under air/water spray.

- Trim with very fine diamonds under air/water spray.
- Smooth with graded, abrasive rubber polishing points under air/water spray.
- Polish with Soflex discs under air/water spray.
- Apply a low-viscosity resin glaze containing a poly(alkenoic acid).

Maturation

For the first 6 months after placement, since chemical maturation will continue for some considerable time, be prepared to cover the restoration with a single-component, very low-viscosity, light-activated bonding resin if it is to be exposed to air for longer than a few minutes.

Type II.2: restorative reinforced cements

Dispensing

The powder/liquid ratio is important.

Capsulated

The powder/liquid ratio is already set. Follow the manufacturer's directions carefully when activating the capsule.

Hand dispensing

When dispensing the powder, follow the manufacturer's directions. In particular:
- Shake the bottle
- Spoon out the powder carefully.

It is very easy to:
- Have voids in the powder and therefore under-dispense
- Have spare powder on the back of the spoon or the handle and therefore over-dispense.

When dispensing the liquid:
- Turn the bottle horizontal for a moment, then pause before inverting completely to ensure dispensing a clean drop.
- Count the drops.

Mix half the powder at a time and complete the mix quickly. The chemical reaction begins **immediately**, and prolonged mixing will only break up the newly formed polymer chains.

Conditioning the tooth

- To gain optimum adhesion, remove the smear layer, plaque, pellicle and any other contaminants to ensure that the dentine and enamel are in a clean condition ready for full chemical union.
- Alternatively, apply a mineralizing solution.

Prepared cavity

Apply 10% poly(acrylic acid) on a cotton pledget for 10–15 seconds only. Wash thoroughly with air/water spray for 20 seconds. Dry lightly, do not dehydrate.

Placement of the restoration

- Apply the cement to the cavity promptly. Remember, it is beginning to set already.
- Use of a syringe is desirable, since positive placement will minimize porosities and voids.
- Tamp into place using a small plastic sponge held in conveying tweezers.
- Use of a matrix is desirable but not essential. The cement will set in the presence of air, but a matrix will apply pressure and adapt the material more positively to the cavity floor and wall and so minimize porosities and voids.
- **Note carefully**: Probably because of its chemical affinity for both tooth structure and the material of the matrix strip, the cement will not flow far in advance of the tip of the syringe. Therefore place the tip of the syringe right to the floor of the cavity, or right to the end of the tunnel. Begin to syringe and withdraw at the same time.

Protection of the new restoration

- This cement is completely resistant to water uptake 6 minutes after starting to mix. The application of a protective layer is therefore not required.
- However, if left exposed for longer than 10 minutes, for example under a rubber dam, it will dehydrate and crack. If it is necessary to leave it exposed then it should be protected with a resin-bonding agent after polishing.

Polishing

Six minutes after starting to mix the cement, contour and polish as required—always under air/water spray.
- Trim with very fine diamonds under air/water spray.
- Smooth with graded abrasive rubber polishing points under air/water spray.
- Polish with Soflex discs under air/water spray.

Type III: lining cements

Dispensing

The powder/liquid ratio is important.

Capsulated

The powder/liquid ratio is already set. Follow the manufacturer's directions carefully when activating the capsule.

Hand dispensing

When dispensing the powder, follow the manufacturer's directions. In particular:

- Shake the bottle
- Spoon out the powder carefully.

It is very easy to:

- Have voids in the powder and therefore under-dispense
- Have spare powder on the back of the spoon or the handle and therefore over-dispense.

When dispensing the liquid:

- Turn the bottle horizontal for a moment, then pause before inverting completely to ensure dispensing a clean drop.
- Count the drops.

Mix half the powder at a time and complete the mix quickly. The chemical reaction begins **immediately**, and prolonged mixing will only break up the newly formed polymer chains.

Conditioning the tooth

- To gain optimum adhesion, remove the smear layer, plaque, pellicle and any other contaminants to ensure that the dentine and enamel are in a clean condition ready for full chemical union.
- Alternatively, apply a mineralizing solution.

Prepared cavity

Apply 10% poly(acrylic acid) on a cotton pledget for 10–15 seconds only. Wash thoroughly with air/water spray for 20 seconds. Dry lightly. Do not dehydrate.

If adhesion is not necessary (for example, when placing a lining under an amalgam restoration), omit the conditioning phase.

Placement of the cement

Auto cure cements

At the prescribed powder/liquid ratio, lining cements are very thin and flow easily. Note that they set rapidly, and working time is limited. By the 'tacky' stage, no further adhesion is available. Flow into place with a small applicator, or use a syringe if placing the cement in bulk.

Dual cure cements

These cements are also thin and flow readily. They require a minimum of 20 seconds' exposure to the activator light and are set on command.

Protection of the cement

- The auto cure cement is set and resistant to water loss approximately 6 minutes from starting to mix, so protection is not required.
- However, if left exposed for longer than 10 minutes, it is likely to dehydrate and crack. Therefore proceed promptly and complete the restoration.
- The dual cure is set on command, and is then resistant to water exchange.

Glass-ionomer/composite resin lamination

Glass-ionomer cement is the base for composite resin in the so-called *sandwich technique*. The glass-ionomer cement will provide union with the dentine, and the composite resin will unite strongly with the enamel.

Selection of glass-ionomer cement

- As optimum strength is required, use the strongest cement available, with a high powder/liquid ratio.
- If aesthetics is important, use a Type II.1 restorative aesthetic dual cure cement.
- Always use a radiopaque cement.

Dispensing

The powder/liquid ratio is important.

Capsulated

- The powder/liquid ratio is already set. Follow the manufacturer's directions carefully when activating the capsule.

Hand dispensing

When dispensing the powder, follow the manufacturer's directions. In particular:

- Shake the bottle
- Spoon out the powder carefully.

It is very easy to:

- Have voids in the powder and therefore under-dispense
- Have spare powder on the back of the spoon or the handle and therefore over-dispense.

When dispensing the liquid:

- Turn the bottle horizontal for a moment, then pause before inverting completely to ensure dispensing a clean drop.
- Count the drops.

Mix half the powder at a time and complete the mix quickly. The chemical reaction begins **immediately**, and prolonged mixing will only break up the newly formed polymer chains.

Conditioning the tooth

- To gain optimum adhesion, remove the smear layer, plaque, pellicle and any other contaminants to ensure that the dentine and enamel are in a clean condition ready for full chemical union.
- Alternatively, apply a mineralizing solution.

Prepared cavity

- Apply 10% poly(acrylic acid) on a cotton pledget for 10–15 seconds only. Wash thoroughly with air/water spray for 20 seconds. Dry lightly. Do not dehydrate.

Erosion lesion

- Clean lightly with a slurry of pumice and water. Wash thoroughly with air/water spray and dry lightly. Condition with 10% poly(acrylic acid) and wash again. Dry but do not dehydrate.

Placement of the cement

If using a dual cure cement:

- Load the cavity generously to cover the entire dentine walls and build incrementally at least 2 mm above the gingival floor using a matrix as required.
- Light-activate from various directions to ensure adequate activation. **It is not possible to over-light-activate.**

If using a Type II.1 auto cure cement:

- Fill the cavity with the cement of choice, making sure that all the dentine is covered. Build up at least 2 mm above the gingival margin, using a matrix to support the cement if required.
- At 4 minutes from the start of mix, cover the cement with a generous layer of single-component low-viscosity, light-activated bonding resin and light-activate. Leave undisturbed for 20 minutes. Only then proceed to place the composite resin.

If using a Type II.2 reinforced cement:

- Fill the cavity with the cement of choice, making sure that all the dentine is covered. Build up at least 2 mm above the gingival margin towards the contact area, using a matrix to support the cement, if required.
- At 6 minutes from the start of mix, proceed to place the composite resin.

If using a Type III cement:

- Use a low powder/liquid ratio of 1.5–1.0 only if the entire cavity is surrounded by enamel strong enough to provide an enamel-bonded margin. Cover all dentinal tubules with a layer of cement at least 1 mm thick. Etching of the cement is optional under these circumstances.
- Use a high powder/liquid ratio of 3 : 1 or greater if any margin is in dentine or the remaining enamel is weak and friable. Overfill the cavity with the cement of choice, making sure that all dentine is covered. Build up at least 2 mm above the gingival margin towards the contact area, using a matrix for support.
- At 6 minutes from the start of mix, proceed to place the composite resin.

Placement of composite resin

Once the cement is set, proceed as follows:

- Trim the cement with very fine diamonds under air/water spray to final cavity outline. Remove single-component, low-viscosity, light-activated bonding resin from areas to be etched, including the enamel. Leave the dentine covered, especially at the gingival margin.
- Bevel the enamel margins as required. Wash and dry lightly.
- Place etchant over enamel and glass-ionomer cement. After 15 seconds, wash thoroughly for 30 seconds and dry, but do not dehydrate. Note that it is unnecessary to etch a dual cure cement, but acid on the cement will do no harm.
- Apply resin bonding agent, blow off excess and light-activate.
- Apply the composite resin and, building incrementally, complete the restoration.

Appendix

BOX E CAVITY PREPARATION INSTRUMENTS

There is a very extensive array of cutting instruments available to the profession for the preparation of a cavity, and selection of the most appropriate is often difficult. The following list is presented as a starting point only, in full recognition that practically all manufacturers of dental rotary cutting instruments will have their version of this list.

The main principle involved is preservation of remaining tooth structure, and each of these groups of burs have been selected with this in mind.

One technique that is of great value in controlling the amount of tooth removed during cavity preparation is the use of intermediate high speed, namely 40 000–60 000 revolutions/min under air/water spray. This provides for excellent tactile sense, while at the same time allowing tooth removal at a sufficiently economical speed, particularly when preparing such fine surgical-type cavities as advocated here.

Diamond stones

(*a*) Tapered stones for entering, defining:	Intensiv 206
Small cylinder for entering:	Horico FG 106 010
Very fine taper for fissures:	Abrasive Technology MFS 201 MF 1

Steel burs, latch type

(*b*) Tapered fissure bur TF XC 700:	38/010
Small round for caries removal:	1/011–1/016
Long-shank round:	1/012–016 ELA
Extra long-shank:	Moller Pulp bur, Meisinger 191/120–180

a

b

BOX F SUITABLE MATRICES

Class I/fissure seal

- If the matrix requires considerable strength, use Hawe Cervical Matrix no. 723 and preshape on the tooth (see Figure 3.6).
- If the matrix requires only moderate strength, use a small section of lead foil from the back of an X-ray film. Cut it to shape and apply a very light film of low-viscosity, light-activated resin or vaseline on the undersurface. It will now form to shape under finger pressure and peel readily from the set cement.
- If the matrix does not require any strength at all, use a small piece of domestic-type Glad Wrap cut to shape. Adapt with finger pressure.

Class II

- If the matrix requires considerable strength, use a conventional mild steel matrix strip either alone or in a retainer. Apply a thin coating of low-viscosity, light-activated resin or vaseline to the inner surface before seating (see Figure 5.13).
- If the matrix requires only moderate strength, use a regular mylar strip, cut to length and wedged as required (see Figure 6.71).

Class III

- Use a regular mylar strip. Cut to length and wedge as required.

Class V

- For the placement of a dual cure cement use a preformed translucent matrix such as that supplied by Ivoclar (see Figure 3.20).
- When placing an auto cure cement, preform a Hawe Cervical Matrix nos. 719–723. These have already been pretreated to allow separation from the set cement (see Figure 4.8).
- For complex two- and three-surface Class V cavities, cut heavy tin foil to shape, and support as required with greenstick compound. Cut a hole in a strategic position with a round bur (1/018) and syringe into place through the hole.

BOX G WEDGES

The purpose of a wedge is twofold. It can be used to support the gingival margin of a matrix band or to gain space between two teeth and thereby improve the strength of the contact point. It can fulfil both purposes at once.

To support the gingival margin of a matrix band:

- Use a wooden wedge, but take care not to distort the matrix band.
- If the matrix band is frail and likely to distort under pressure, use a small pledget of cotton wool soaked in a light-activated resin bonding agent. Place this interproximally as required and light-activate. This will give sufficient support to the matrix to allow positioning of the glass-ionomer cement without displacement or production of an overhang.
- If the matrix is of heavy tin foil, support as required with greenstick compound.

To gain space between two teeth:

- Plan ahead of time and place an orthodontic rubber ring one week before restoration.
- Place a wooden wedge before beginning cavity preparation. Adjust the pressure periodically prior to placing the matrix.
- If placing a posterior composite resin restoration, use a plastic light-transmitting wedge in the same manner.

Reading list

Aboush YEY, Jenkins CBG, An evaluation of the bonding of glass-ionomer restoratives to dentine and enamel, *Br Dent J* (1986) **161**: 179–84.

Aboush YEY, Jenkins CBG, The effect of poly(acrylic acid) cleanser on the adhesion of a glass polyalkenoate cement to enamel and dentine, *J Dent* (1987) **15**: 147–52.

Akinmade AO, Nicholson JW, Review—Glass-ionomer cements as adhesives. Part I. Fundamental aspects and their clinical relevance, *J Mater Sci in Medicine* (1993) **4**: 95–101.

Bass EV, Wing G, The mixing of encapsulated glass-ionomer cement restorative materials, *Aust Dent J* (1988) **33**: 243.

Berg JH, Antibacterial effect of glass ionomer silver cermet restorations, *Pediatr Dent* (1990) **12**: 20–3.

Blagojevic B, Mount GJ, A laboratory study of glass-ionomer cements in relation to clinical dentistry, *Aust Dent J* (1988) **33**: 320–1.

Brackett WW, Metz JE, Performance of a glass ionomer luting cement over five years in a general practice, *J Prosthet Dent* (1992) **67**: 59–61.

Brown KB, Swartz ML, Cochran MA, Phillips RW, The glass ionomer lined cervical composite restoration, *Oper Dent* (1993) **18**: 17–27.

Cattani-Lorente MA, Godin C, Meyer AM, Early strength of glass ionomer cement, *Dent Mater* (1993) **9**: 57–62.

Causton BE, The physical and mechanical consequences of exposing glass-ionomer cement to water during setting, *Biomaterials* (1982) **2**: 112–4.

Causton BE, Johnson NW, Improvement of polycarboxylate adhesion to dentine by the use of a new calcifying solution, *Br Dent J* (1982) **152**: 9–11.

Charlton DG, Moore PK, Schwartz ML, Direct surface pH determinations of setting cements, *Oper Dent* (1991) **16**: 231–6.

Cranfield M, Kuhn AT, Winter G, Factors relating to the rates of fluoride release from a glass-ionomer cement, *J Dent* (1982) **10**: 333–4.

Dahl BL, Øilo G, Retentive properties of luting cements: an in vitro investigation, *Dent Mater* (1986) **2**: 17–21.

De Wald JP, Arcoria CJ, Ferracane JL, Evaluation of glass cermet cores under cast crowns, *Dent Mater* (1990) **6**: 129–32.

Earl MSA, Mount GJ, Hume WR, Effect of varnishes and other surface treatments on water movement across the glass-ionomer cement surface, *Aust Dent J* (1985) **30**: 298–301.

Earl MSA, Mount GJ, Hume WR, Effect of varnishes and other surface treatments on water movement across the glass-ionomer cement surface II, *Aust Dent J* (1989) **34**: 326–9.

Fitzgerald M, Heyes RJ, Heyes DR et al, An evaluation of a glass-ionomer luting agent: bacterial leakage, *J Am Dent Assoc* (1987) **114**: 783–6.

Forsten L, Fluoride release from a glass-ionomer cement, *Scand J Dent Res* (1977) **85**: 503–4.

Forsten L, Short- and long-term fluoride release from glass ionomers and other fluoride-containing filling materials in vitro, *Scan J Dent Res* (1990) **98**: 179–85.

Forsten L, Fluoride release and uptake by five year old glass-ionomer specimens, 2nd NOF/CED Joint Meeting, Kolding, Denmark 1993 (abst 005).

Fricker JP, A 12-month clinical evaluation of a glass polyalkenoate cement for the bonding of orthodontic brackets, *Am J Ortho & Dentofac Orthoped* (1992) **101**: 381–4.

Fricker J, Hirota K, Tamiya Y, The effects of temperature on the setting of glass ionomer (polyalkenoate) cement, *Aust Dent J* (1991) **36**: 240–2.

Fuss J, Mount GJ, Makinson OF, The effect of etching on a number of glass-ionomer cements, *Aust Dent J* (1990) **35**: 338–44.

Garcia R, Caffesse RG, Charbeneau GT, Gingival tissue response to restoration of deficient cervical contours using a glass-ionomer material—a 12 month report, *J Prosthet Dent* (1981) **46**: 393–8.

Garcia-Godoy F, The preventive glass-ionomer restoration, *Quint Int* (1986) **17**: 617–9.

Garcia-Godoy F, Marshall DM, Mount GJ, Microleakage of glass-ionomer tunnel restorations, *Am J Dent* (1988) **1**: 53–6.

Geiger SB, Weiner S, Fluoridated carbonatoapatite in the intermediate layer between glass ionomer and dentine, *Dent Mater* (1993) **9**: 33–6.

Glantz P-O, Adhesion to teeth, *Int Dent J* (1977) **27**: 324–32.

Going RE, Loesche WG, Grainger DA et al, The viability of microorganisms in carious lesions five years after covering with a fissure sealant, *J Am Dent Assoc* (1978) **97**: 455–62.

Heithersay GS, Tissue responses in the rat to trichloracetic acid—an agent used in the treatment of invasive cervical resorption, *Aust Dent J* (1988) **33**: 451–61.

Heys RJ, Fitzgerald M, Heys DR et al, An evaluation of a glass-ionomer cement luting agent: pulpal histological response, *J Am Dent Assoc* (1987) **114**: 607–11.

Hicks MJ, Artificial lesion formation around glass-ionomer restorations in root surfaces: a histological study, *Gerodontics* (1986) **2**: 108–13.

Hicks MJ, Flaitz CM, Silverstone LM, Secondary caries formation in vitro around glass-ionomer restorations, *Quint Int* (1986) **17**: 527–32.

Hood JAA, Childs WA, Evans DF, Bond strengths of glass-ionomer and polycarboxylate cements to dentine, *NZ Dent J* (1981) **77**: 141–4.

Hotz P, McLean JW, Sced I et al, The bonding of glass-ionomer cements to metal and tooth substrates, *Br Dent J* (1977) **142**: 41–7.

Hume WR, Mount GJ, In vitro studies on the potential for pulpal cytotoxicity of glass-ionomer cements, *J Dent Res* (1988) **67**: 915–8.

Hunt PR, Micro conservative restorations for approximal carious lesions, *J Am Dent Assoc* (1990) **120**: 37–40.

Kawahara H, Iminishi Y, Oshima H, Biological evaluation of a glass-ionomer cement, *J Dent Res* (1979) **58**: 1080–6.

Kidd EAM, Cavity sealing ability of composite and glass-ionomer cement restorations: an assessment in vitro, *Br Dent J* (1978) **144**: 139–42.

Kirby RE, Knobloch L, Strength characteristics of glass ionomer cements, *Oper Dent* (1992) **17**: 170–4.

Knibbs PJ, Glass-ionomer cement: ten years of clinical use, *J Oral Rehab* (1988) **15**: 103–15.

Knibbs PJ, Plant CG, Pearson GJ, A clinical assessment of an anhydrous glass-ionomer cement, *Br Dent J* (1986) **161**: 99–103.

Knight GM, The use of adhesive materials in the conservative restoration of selected posterior teeth, *Aust Dent J* (1984) **29**: 324–7.

Kovarik RE, Breeding LC, Caughman WF, Fatigue life of three core materials under simulated chewing conditions, *J Prosthet Dent* (1992) **68**: 584–90.

Lewis BA, Burgess JO, Grey SE, Mechanical properties of dental base materials, *Am J Dent* (1992) **5**: 69–72.

Lloyd CH, Butchart DGM, The retention of core composites, glass ionomers and cermets by a self threading pin: the influence of fracture toughness upon failure, *Dent Mater* (1990) **6**: 185–8.

McComb D, Retention of castings with a glass-ionomer cement, *J Prosthet Dent* (1982) **48**: 285–8.

McComb D, Ericson D, Antimicrobial action of new proprietary lining cements, *J Dent Res* (1987) **66**: 1025–8.

McConnell RJ, Boksman L, Hunter JK et al, Effect of restorative materials on the adaptation of two bases and a dentine bonding agent to internal cavity walls, *Quint Int* (1987) **17**: 703–10.

McLean JW, Glass ionomer cements, *Br Dent J* (1988) **164**: 293–529.

McLean JW, Limitations of posterior composite resins and extending their use with glass ionomer cements, *Quint Int* (1987) **18**: 517–29.

McLean JW, A new method of bonding dental cements and porcelain to metal surfaces, *Oper Dent* (1977) **2**: 130–42.

McLean JW, Gasser O, Glass cermet cements, *Quint Int* (1985) **5**: 333–43.

McLean JW, Powis DR, Prosser HJ et al, The use of glass-ionomer cements in bonding composite resins to dentine, *Br Dent J* (1985) **158**: 410.

McLean JW, Wilson AD, The clinical development of the glass-ionomer cements I: formulations and properties, *Aust Dent J* (1977) **22**: 31–6.

McLean JW, Wilson AD, The clinical development of the glass-ionomer cements II: some clinical applications, *Aust Dent J* (1977) **22**: 120–7.

McLean JW, Wilson AD, The clinical development of the glass-ionomer cements III: the erosion lesion, *Aust Dent J* (1977) **22**: 190–5.

McLean JW, Wilson AD, Fissure sealing and filling with an adhesive glass ionomer cement, *Br Dent J* (1977) **136**: 269–70.

McLean JW, Wilson AD, Prosser HJ, Development and use of water-hardening glass-ionomer luting cements, *J Prosthet Dent* (1984) **52**: 175–81.

Maldonado A, Swartz ML, Philips RW, An in vitro study of certain properties of a glass-ionomer cement, *J Am Dent Assoc* (1978) **96**: 785–91.

Matis BA, Cochran M, Carlton T et al, Clinical evaluation and early finishing of glass-ionomer restorative materials, *Oper Dent* (1988) **13**: 74–80.

Mount GJ, Restoration with glass-ionomer cement: requirements for clinical success, *Oper Dent* (1981) **6**: 59–65.

Mount GJ, The use of glass-ionomer cement in clinical practice, *Dental Outlook* (1982) **8**: 37–44.

Mount GJ, Glass-ionomer cements: clinical considerations. In: Clarke JW, ed, *Clinical dentistry* (Harper and Row: Philadelphia 1984) Chap 20A.

Mount GJ, Root surface caries: a recurrent dilemma, *Aust Dent J* (1986) **31**: 288–91.

Mount GJ, Longevity of glass ionomer cements, *J Prosthet Dent* (1986) **55**: 682–4.

Mount GJ, Root surface caries—a new emphasis, *Periodontology* (1987) **8**: 31–7.

Mount GJ, Glass ionomer cements in gerodontics. A status report for the American Journal of Dentistry, *Am J Dent* (1988) **1**: 123–8.

Mount GJ, Glass-ionomer cements—obtaining optimum aesthetic results, *Dental Outlook* (1988) **14**: 3–7.

Mount GJ, A method of testing the union between glass-ionomer cement and composite resin, *Aust Dent J* (1988) **33**: 462–6.

Mount GJ, Clinical considerations in the prevention and restoration of root surface caries, *Am J Dent* (1988) **1**: 163–8.

Mount GJ, The wettability of bonding resins used in the composite resin/glass-ionomer 'sandwich' technique, *Aust Dent J* (1989) **34**: 32–5.

Mount GJ, The tensile strength of the union between various glass-ionomer cements and various composite resins, *Aust Dent J* (1989) **34**: 136–46.

Mount GJ, Clinical requirements for a successful 'sandwich'—dentine to glass-ionomer cement to composite resin, *Aust Dent J* (1989) **34**: 259–65.

Mount GJ, Aesthetics with glass ionomer cements and the 'sandwich technique', *Quint Int* (1990) **21**: 93–101.

Mount GJ, Restoration of eroded areas, *J Am Dent Assoc* (1990) **120**: 31–5.

Mount GJ, Adhesion of glass ionomer cement in the clinical environment, *Oper Dent* (1991) **16**: 141–8.

Mount GJ, Making the most of glass ionomer cements: 1 and 2, *Dental Update* (1991) **18**: 276–9 and 324–8.

Mount GJ, Makinson OF, Clinical characteristics of a glass-ionomer cement, *Br Dent J* (1978) **145**: 67–71.

Mount GJ, Makinson OF, Glass-ionomer restorative cements: clinical implications of the setting reaction, *Oper Dent* (1982) **7**: 134–41.

Murchison DF, Moore BK, Influence of curing time and distance hardness of eight light cured liners, *Oper Dent* (1992) **17**: 135–41.

Ngo H, Earl MSA, Mount GJ, Glass-ionomer cements: a 12 month evaluation, *J Prosthet Dent* (1986) **55**: 203–5.

Nicholson JW, Anstice HM, McLean JW, A preliminary report on the effect of storage in water on the properties of commercial light cured glass ionomer cements, *Br Dent J* (1992) **173**: 98–101.

Øilo G, Evje DM, Film thickness of dental luting cements, *Dent Mater* (1986) **2**: 85–9.

Palenik CJ, Bhnen MJ, Setcos JC, Miller CH, Inhibition of microbial adherance and growth by various glass ionomer cements in vitro, *Dent Mater* (1992) **8**: 16–20.

Pameijer CH, Segal E, Richardson J, Pulpal response to a glass-ionomer cement in primates, *J Prosthet Dent* (1981) **46**: 36–40.

Pameijer CH, Stanley HR, Bio-compatibility of a glass-ionomer luting agent in primates. Part I, *Am J Dent* (1988) **1**: 71–6.

Papa J, Wilson PR, Tyas MJ, Tunnel restorations: a review, *J Esthetic Dent* (1992), **4**: Suppl 4–9.

Phillips RW, The restoration of eroded cervical areas, *CDS Review* (1980) **73**: 31–2.

Phillips RW, Swartz ML, Lund MS et al, In vivo disintegration of luting cements, *J Am Dent Assoc* (1987) **114**: 489–92.

Powell LV, Gordon GE, Johnson GH, Clinical comparison of Class V resin composite and glass ionomer cement restorations, *Am J Dent* (1992) **5**: 249–52.

Powis, DR, Folleras T, Merson SA et al, Improved adhesion of a glass-ionomer cement to dentine and enamel, *J Dent Res* (1982) **61**: 1416–22.

Prodger TE, Symons M, Aspa adhesion study, *Br Dent J* (1977) **143**: 266–77.

Prosser HJ, Characterisation of glass-ionomer cements. 7: The physical properties of current materials, *J Dent* (1984) **12**: 231–40.

Prosser HJ, Powis DR, Wilson AD, Glass-ionomer cements of improved flexural strength, *J Dent Res* (1986) **65**: 146–8.

Reinhardt JW, Swift EJ, Bolden AJ, A national survey on the use of glass ionomer cements, *Oper Dent* (1993) **18**: 56–60.

Reisbick MH, Working qualities of glass-ionomer cement, *J Prosthet Dent* (1981) **46**: 525–30.

Serra MC, Cury JA, The in vitro effect of glass ionomer cement restoration on enamel subjected to demineralisation and remineralisation model, *Quint Int* (1992) **23**: 143–7.

Sidhu SK, Sealing effectiveness of light cured glass ionomer cement liners, *J Prosthet Dent* (1992) **68**: 891–4.

Sidhu SK, Henderson LJ, Dentine adhesives and micro-leakage in cervical resin composites, *Am J Dent* (1992) **5**: 240–4.

Simonsen RJ, Retention and effectiveness of dental sealant after 15 years, *J Am Dent Assoc* (1991) **122**: 32–42.

Simonsen RJ, Stallard RE, Sealant-restorations utilizing a diluted filled composite resin: one year results, *Quint Int* (1978) **8**: 77–84.

Skorland KK, Bacterial accumulation on silicate and composite materials, *J Biol Buccale* (1976) **4**: 315–22.

Smith DC, Ruse ND, Acidity of glass-ionomer cements during setting and its relation to pulp sensitivity, *J Am Dent Assoc* (1986) **112**: 654–7.

Sneed WD, Luper SW, Sheer bond strength of a composite resin to an etched glass-ionomer, *Dent Mater* (1985) **1**: 127–8.

Stokes AN, Proportioning and temperature effects on the manipulation of glass ionomer cements, *J Dent Res* (1980) **59** (spec. issue Pt I): 1782.

Swartz ML, Phillips RW, Clark HE, Long term fluoride release from certain cements, *J Dent Res* (1984) **63**: 158–60 (abst).

Tam LE, McComb D, Pulver F, Physical properties of light cured lining materials, *Oper Dent* (1991) **16**: 210–17.

Thornton JB, Retief DM, Bradley EL, Fluoride release from and tensile bond strength of Ketac Fil and Ketac Silver to enamel and dentine, *Dent Mater* (1986) **2**: 241–5.

Tobias RS, Brown RM, Plant CG et al, Pulpal response to a glass-ionomer cement, *Br Dent J* (1978) **144**: 345–50.

Tviet AB, Gjerdet NR, Fluoride release from a fluoride-containing amalgam, a glass-ionomer cement and a silicate cement, *J Oral Rehabil* (1981) **8**: 237–41.

Tyas MJ, Clinical performance of adhesive restorative materials for cervical abrasion lesions, *J Dent Res* (1983) **62**: 646 (abst S 12).

Tyas MJ, Cariostatic effect of glass ionomer cement: a five year clinical study, *Aust Dent J* (1991) **36**: 236–9.

Vougiouklakis G, Smith DC, Lipton S, Evaluation of the bonding of cervical restorative materials, *J Oral Rehabil* (1982) **9**: 231–51.

Walls AWG, Glass polyalkenoate (glass-ionomer) cement: a review, *J Dent* (1986) **14**: 231–46.

Warren JA, Soderholm K-JM, Bonding amalgam to glass-ionomer with polyacrylic acid, *Dent Mater* (1988) **4**: 191–6.

Watson TF, A confocal microscopic study of some factors affecting the adaptation of a light-cured glass ionomer to tooth tissue, *J Dent Res* (1990) **69**: 1531–8.

Watson TF, Billington RW, Williams JA, The interfacial region of the tooth/glass ionomer restoration: a confocal optical microscope study, *Am Dent J* (1991) **4**: 303–10.

Welbury RR, Factors affecting the bond strength of composite resin to etched glass-ionomer cement, *J Dent* (1988) **16**: 188–93.

White SN, Zhaokun Yu, Film thickness of new adhesive luting agents, *J Prosthet Dent* (1992) **67**: 782–5.

White SN, Zhaokun Yu, Kipnis V, Effect of seating force on film thickness of new adhesive luting agents, *J Prosthet Dent* (1992) **68**: 476–81.

Wilson AD, McLean JW, *Glass-ionomer cement* (Quintessence: London 1988).

Wilson AD, Crisp S, Lewis BG et al, Experimental luting agents based on the glass-ionomer cements, *Br Dent J* (1977) **142**: 117–22.

Wong TCC, Bryant RW, Glass-ionomer cements: dispensing and strength, *Aust Dent J* (1985) **30**: 336–40.

Wong TCC, Bryant RW, Glass-ionomer cements: some factors in film thickness, *Aust Dent J* (1986) **31**: 81–5.

Yao K, Chien M, Kohara O et al, Finishing of glass ionomer cement, *J Osaka Dent Univ* (1990) **24**: 141–7.

Index

Page numbers in *italic* refer to the illustrations

Clinical Techniques in Dentistry

An Atlas of Glass-Ionomer Cements

A Clinician's Guide

SECOND EDITION

Graham J Mount AM, BDS, DDSc, FRACDS, FICD, FADI, is in private practice based in Adelaide, Australia. Since the formal introduction of glass-ionomer cements in 1976 Dr Mount has been closely involved with their development, carrying out research at the University of Adelaide as well as clinical trials in his private practice. He has lectured extensively around the world, including invitations to Amsterdam, Chicago, Dublin, Gothenburg, Kuala Lumpur, London, Philadelphia, Singapore and South America.

Glass-ionomer cements have proved their worth in the area of restorative dentistry, and the dental profession has now recognized their unique properties, which include the ability to ion-exchange at the tooth interface, leach fluoride and maintain marginal seal over long periods. The author is a pioneer in the field and presents the practising dentist with the relevant, concise and state-of-the-art information needed for successful restorations; the text is profusely illustrated with clinical slides showing the long-term results.

The second edition of this successful volume has been fully revised and updated, and now includes extensive discussion of the new dual cure cements with the consequent modifications to clinical techniques.

Contents ■ Description of glass-ionomer cements ■ Type I: luting cements ■ Type II.1: restorative aesthetic cements ■ Type II.2: restorative reinforced cements ■ Type III: lining cements ■ Modified cavity designs suitable for restoration with glass-ionomer cements ■ Instructions for dental assistants ■ Condensed instructions: all types

With over 300 full-colour and black-and-white photographs and radiographs and line drawings

Review of the first edition:

'All the techniques are there, superbly illustrated with carefully reproduced colour photographs backed up by a lively and highly readable text.'

Dental Update

ISBN 1-85317-183-2

9 781853 171833

MARTIN DUNITZ